PRICE $5.00

Model JQE 36—15 (M)

Serial No. H92036

# INSTRUCTION MANUAL

KEPCO®

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JQE design group

*COMPACT*

# POWER SUPPLY

**Model JQE 36—15 (M)**

**Serial No.** H92036

# INSTRUCTION MANUAL

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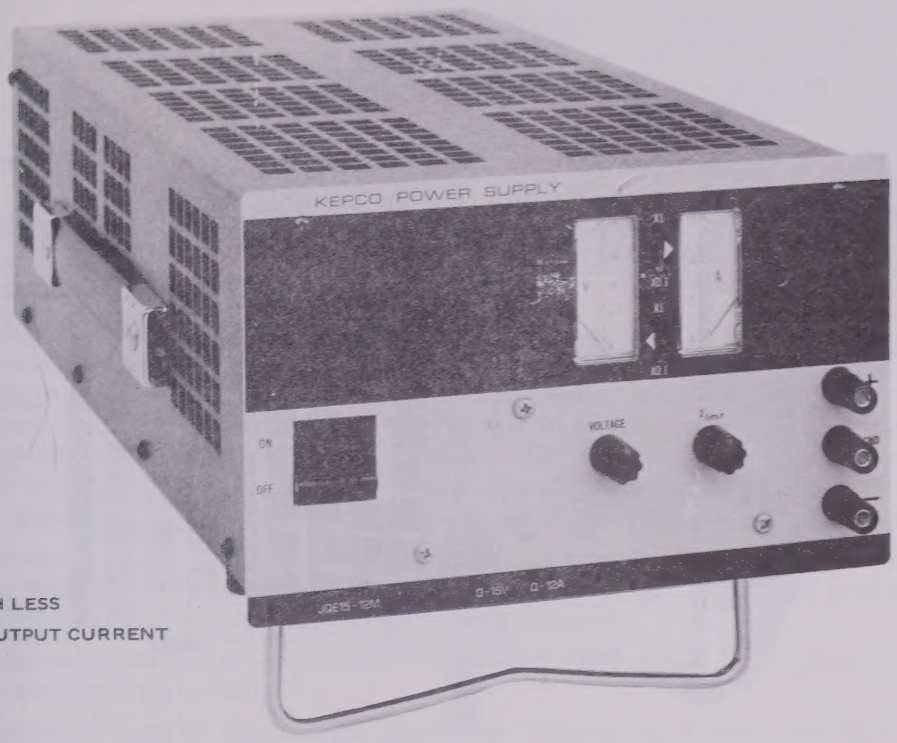
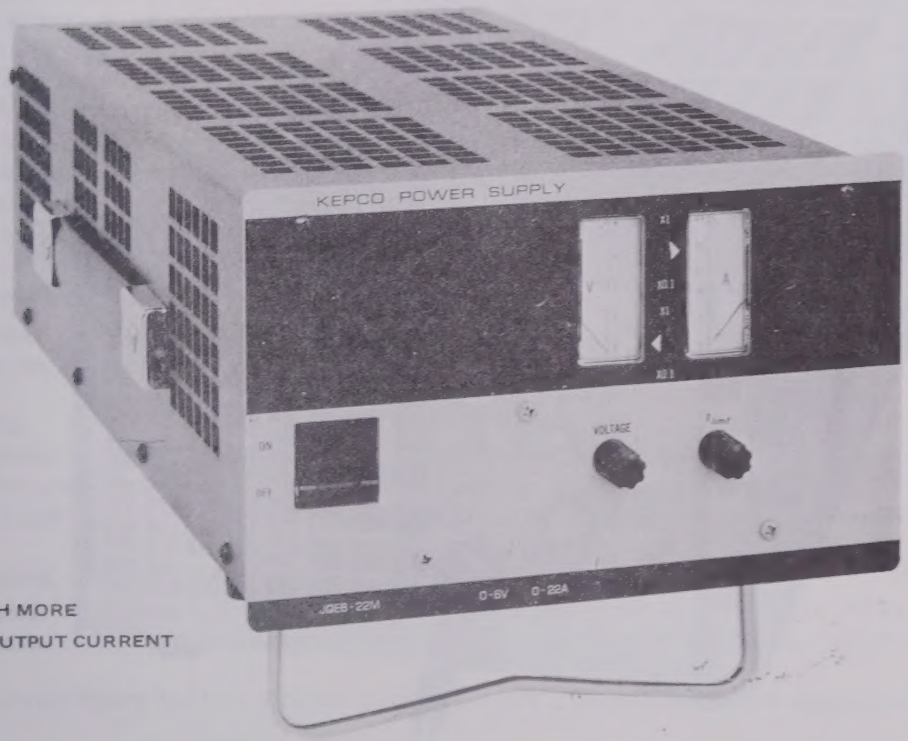
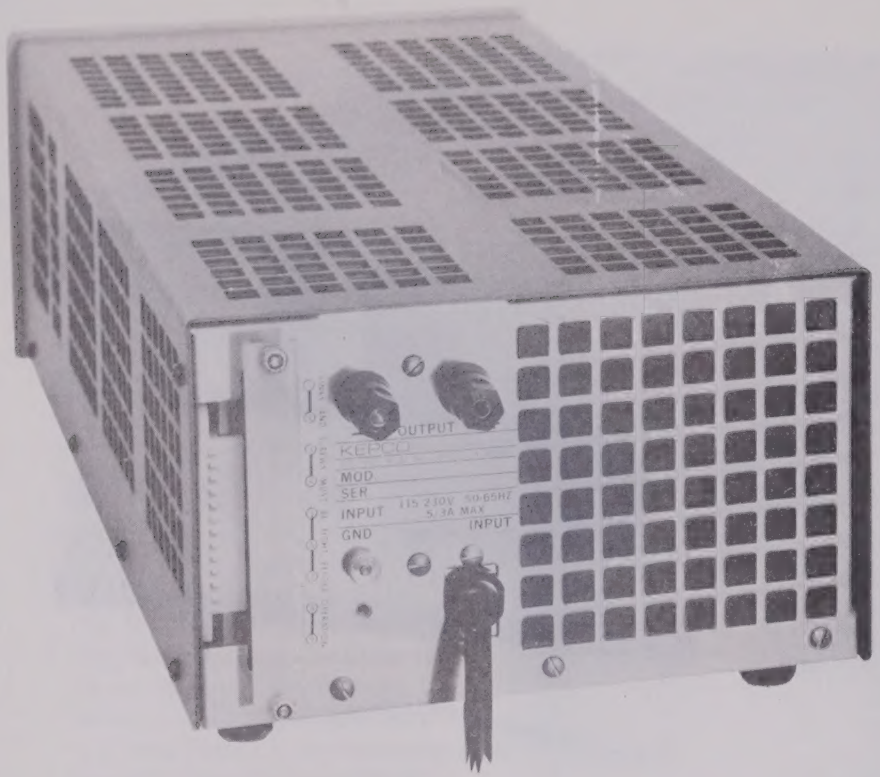



a) MODELS WITH LESS
THAN 15A DC OUTPUT CURRENT

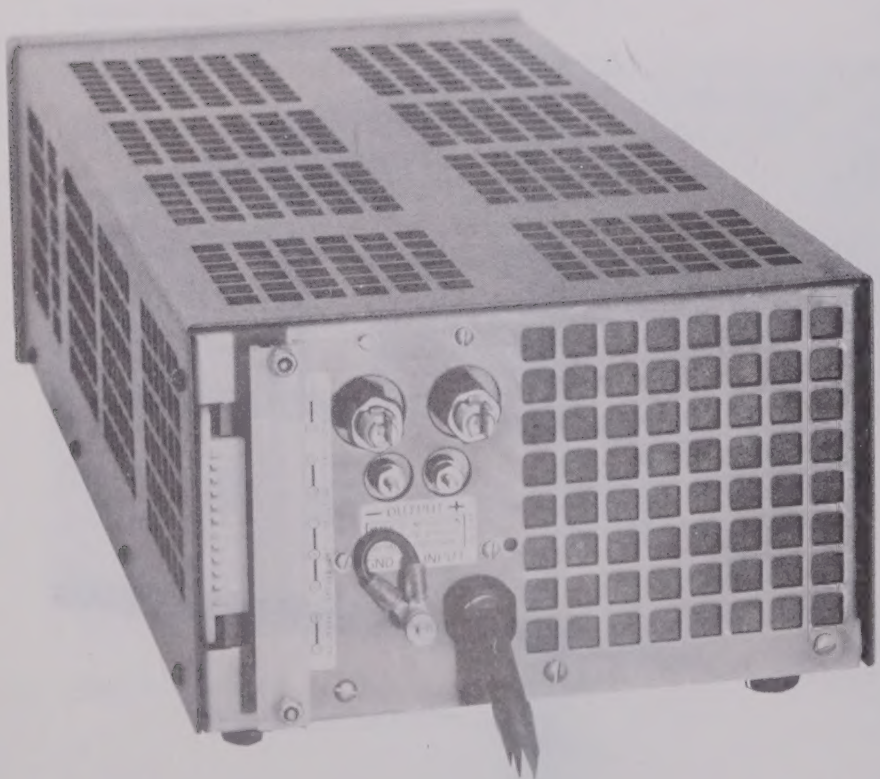



b) MODELS WITH MORE
THAN 15A DC OUTPUT CURRENT

FIG. 1-1 JQE HALF-RACK POWER SUPPLY, TYPICAL FRONT VIEWS




a) MODELS WITH LESS THAN 25A DC OUTPUT CURRENT




b) MODELS WITH 25A DC AND 45A DC OUTPUT CURRENT

FIG 1-2 HALF-RACK POWER SUPPLY, TYPICAL REAR VIEWS

# SECTION I – INTRODUCTION

## 1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation and maintenance of the Kepco JQE "HALF-RACK" Series of Power Supplies.

## 1-3 GENERAL DESCRIPTION

1-4 Kepco Series JQE Power Supplies are general purpose, precision regulated voltage sources in the "half-rack" configuration. JQE Power Supplies feature full range voltage control and current limit adjustment by means of multi-turn front panel controls. JQE power supplies have linear, full-dissipation series-regulators (NPN) driven by an integrated circuit operational amplifier. A sharp current-limit circuit renders the power supply completely short-circuit proof. JQE power supplies may be readily converted to provide constant current by the addition of an external sensing resistor and a "current control". The output of the JQE power supply is completely programmable. All necessary connections are available on terminals at the rear barrier strip.

1-5 The compact design of the Kepco JQE "HALF-RACK" Series was made possible by a unique heatsink design of exceptional efficiency in combination with highly reliable low-noise fans. JQE power supplies feature all-silicon design with conservatively rated components for added reliability.

1-6 JQE power supplies are identical in their mechanical dimensions (Refer to FIG. 1-3) and in their electrical specifications, except as noted in TABLE 1-1.

1-7 OPTIONS. Optional features of Kepco Power Supplies are indicated by a letter following the model designation:

a) JQE Power Supplies with suffix "E" are equipped with an "$E_{io}$ Null" adjustment, which allows exact zero calibration for precision programming applications.

b) JQE Power Supplies with suffix "HS" are optimized for high speed programming. For these models, a special addendum containing all supplementary specifications is provided in the appendix of the manual. The "$E_{io}$ Null"("E") option is automatically included with the "HS" option.

c) JQE Power Supplies with suffix "M" are equipped with two dual range panel meters which permit simultaneous monitoring of the output voltage and output current. Meter range-switches allow for full scale reading of either 10% or 100% of the voltage and current outputs.

d) JQE Power Supplies with suffix "T" have special references which improve the temperature coefficient of the supply (see paragraph 1-11 for specifications).

e) JQE Power Supplies with suffix "VP" are equipped with an overvoltage protector. This electrical "crowbar" shorts the output through a silicon controlled rectifier(SCR) if the output voltage exceeds a preadjustable limit on the protector (see paragraph 1-12 for specifications).

1-8 The main chassis frame of the power supply is constructed from cold-rolled steel, as is the perforated wrap-around cover. Front panel material is aluminum (Refer to FIG. 1-3 for finish).

## 1-9 ACCESSORIES

a) RACK ADAPTOR (FOR TWO UNITS); KEPCO MODEL RA 24. Fits standard EIA rack-dimensions.

b) FILLER PANEL, to cover empty slot if RA 24 is used for one unit only: KEPCO MODEL RFP 24–2.

c) RACK ADAPTOR PANEL: KEPCO MODEL RAP 24–2J for installing meterless models into RA 24.

## 1-10 SPECIFICATIONS, GENERAL

a) AC INPUT: 105 to 125V AC or 210 to 250V AC (selectable, refer to SECTION II), 50 to 65 Hz,* single phase. Refer to the table of general specifications (TABLE 1-1) for the AC input current for each model.

b) OPERATING TEMPERATURE RANGE: (–)20°C to (+)71°C (without derating of the output).

*Consult factory for operation on power line frequencies above 65 Hz.

c) STORAGE TEMPERATURE: –50°C to (+)85°C.

d) COOLING: High efficiency, single bearing fan, (permanently lubricated) with special low noise non-metal blade.

e) ISOLATION: A maximum of 500 volts (DC or p-p) can be connected between chassis and either output terminal.

## 1-11 SPECIFICATIONS,ELECTRICAL

a) Refer to TABLE 1-1 and 1-2.

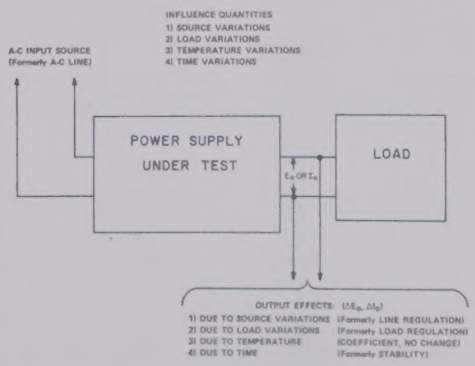
| MODEL | D-C OUTPUT RANGE VOLTS | AMPS | OUTPUT IMPEDANCE OHMS & MICROHENRIES DC–100 Hz | 0.1–1 kHz | (OHMS + μH) 1 kHz–100 kHz | APPROXIMATE MAXIMUM A-C INPUT CURRENT AMPS @ 125V A-C |
|---|---|---|---|---|---|---|
| JQE 6–22 | 0–6 | 0–22 | $14X10^{-6}$ | 0.005 | 0.01+0.5 | 4.2 |
| JQE 6–45 | 0–6 | 0–45 | $7X10^{-6}$ | 0.005 | 0.01+0.5 | 9.0 |
| JQE 15–12 | 0–15 | 0–12 | $63X10^{-6}$ | 0.005 | 0.01+0.5 | 4.0 |
| JQE 15–25 | 0–15 | 0–25 | $30X10^{-6}$ | 0.005 | 0.01+0.5 | 8.4 |
| JQE 25–10 | 0–25 | 0–10 | $125X10^{-6}$ | 0.005 | 0.01+0.5 | 5.3 |
| JQE 25–20 | 0–25 | 0–20 | $63X10^{-6}$ | 0.005 | 0.01+0.5 | 10.5 |
| JQE 36–8 | 0–36 | 0–8 | $225X10^{-6}$ | 0.005 | 0.01+0.5 | 6.0 |
| JQE 36–15 | 0–36 | 0–15 | $120X10^{-6}$ | 0.005 | 0.01+0.5 | 9.5 |
| JQE 55–5 | 0–55 | 0–5 | $550X10^{-6}$ | 0.001 | 0.02+1 | 5.0 |
| JQE 55–10 | 0–55 | 0–10 | $275X10^{-6}$ | 0.01 | 0.02+1 | 9.0 |
| JQE 75–3 | 0–75 | 0–3 | $1.25X10^{-3}$ | 0.005 | 0.01+1 | 4.0 |
| JQE 75–8 | 0–75 | 0–8 | $469X10^{-6}$ | 0.005 | 0.01+1 | 10.0 |
| JQE 100–2.5 | 0–100 | 0–2.5 | $2X10^{-3}$ | 0.005 | 0.02+1 | 4.5 |
| JQE 100–5 | 0–100 | 0–5 | $1.25X10^{-3}$ | 0.05 | 0.02+1 | 8.4 |
| JQE 150–1.5 | 0–150 | 0–1.5 | $5X10^{-3}$ | 0.01 | 0.05+2 | 4.6 |
| JQE 150–3.5 | 0–150 | 0–3.5 | $2.2X10^{-3}$ | 0.01 | 0.05+2 | 8.7 |

NOTE: Specifications for metered models (suffix "M") are identical.

TABLE 1-1 JQE (½ RACK) GROUP , SPECIFICATIONS

**NOTE:** With the introduction of the 1970 Catalog (B-703), Kepco has adopted new technical terms recommended by the International Electrotechnical Commission (IEC). These terms replace or supplement previously used expressions, mainly to avoid difficulties in translation and prevent erroneous interpretations at home and abroad.

As a beginning, Kepco will discontinue the use of the specifications entitled "Line Regulation" and "Load Regulation" because of the long standing (and misleading) connotation that a power supply regulates the line or the load. Instead, Kepco will follow the recommendation of the IEC and speak of the "Output Effects, caused by changes in the Influence Quantities." The "Output Effects" are specified as before, either as a percentage change referred to the maximum specified output voltage ($E_O$) or current ($I_O$) or as an absolute change ($\Delta E_O$, $\Delta I_O$) directly in millivolts or milliamperes or both. The "Influence Quantities" are the "Source Variations" (formerly a-c line variations), the changes in load, temperature or time as previously specified. The illustration below will clarify the use of the new terminology.




b) VOLTAGE RECOVERY TIME: (for step load current), <50 μsec.

c) OVERSHOOT: No output voltage overshoot from turn-on, turn-off, or power failure for output settings above 25% of maximum rated output voltage. Below 25%, output voltage overshoot is a function of load current and is negligible for loads in excess of 10% of the maximum rated load current.

| SPECIFICATION | OUTPUT EFFECTS VOLTAGE MODE | OUTPUT EFFECTS CURRENT MODE*** | VOLTAGE AMPLIFIER OFFSETS**** OFFSET VOLTAGE $\Delta E_{io}$ | OFFSET CURRENT $\Delta I_{io}$ | VOLTAGE REFERENCE (Internal)**** |
|---|---|---|---|---|---|
| OUTPUT RANGE: | 0–100% $E_o$ max. | 1 mA–100% $I_o$ max. | | | Fixed 6.2V ±5% |
| SOURCE: 105–125/210–250V a-c | <0.0005% | <0.005% | <10 μV | <2 nA | 0.0001% |
| LOAD: No load – full load | <0.005% or 0.2 mV* | <0.01% | <200 μV | <5 nA | ——— |
| TIME: 8-hours (drift) | <0.01% or 1 mV* | <0.02 | <20 μV | <2 nA | 0.005% |
| TEMPERATURE: Per °C | <0.01%** | <0.02** | <20 μV | <5 nA | 0.005% |
| RIPPLE: (rms) | <0.2 mV | <0.02% of $I_o$ max. | ——— | ——— | ——— |

*NOTE: Whichever is greater.

**NOTE: Models with suffix "T" have 0.005% and 0.01% per °C Temperature Coefficients in the Voltage and Current Mode respectively.

***NOTE: Current Mode Output Effects ($\Delta I_o$) are measured across the external sensing resistor. This resistor must be a high quality, wirewound unit, with a wattage at least 10 times the actual power dissipated, have a Temperature Coefficient of 20 parts per million or better and drop a sample voltage of 1.0 volt at the measuring current. A resistor built as a 4-terminal network is recommended. Current control is exercised with an external 20 PPM feedback resistor.

****Offsets and the reference contribute to output effect $\Delta E_o$ by the equation $\Delta E_o = \pm\Delta E_{ref}(R_f/R_i) \pm\Delta E_{io}(1 + R_f/R_i) \pm\Delta I_{io}(R_f)$ where $R_f$ is the feedback resistor and $R_i$ is the input resistor from the signal reference. Use the offsets to calculate output effects when external input/feedback elements are substituted for the internal reference and voltage control in special applications.

TABLE 1-2 JQE(½-RACK) ELECTRICAL SPECIFICATIONS

## 1-12 SPECIFICATIONS, PERFORMANCE

a) VOLTAGE CONTROL*: 10 turn precision rheostat at the front panel, resolution: 0.05% of $E_o$ max. Controls the output voltage from zero to $E_o$ max.

b) CURRENT LIMIT CONTROL*: 10 turn vernier control at the front panel permits adjustment of the current limit from 10% to 105% of the maximum rated output current ($I_o$).

c) REMOTE ERROR SENSING: Rear barrier-strip terminals provide for connection of the error sensing leads directly at the load, thus compensating for losses due to load current voltage drops. Up to 0.5V per output lead can be compensated.

d) REMOTE PROGRAMMING: Rear barrier terminals provide for remote control of the power supply by resistance (control loop uses 1 mA with a Programming Ratio of 1000 ohms per volt), or by external control voltage.

e) SERIES/PARALLEL: Series operation of JQE power supplies is possible up to the rated isolation voltage. Parallel operation using "Automatic Parallel" or "Slave-Master" parallel connections may be performed.

f) OVERVOLTAGE PROTECTOR (MODELS WITH SUFFIX "VP")
Electronic "Crowbar" circuit shorts the output through a silicon controlled rectifier (SCR) as soon as the power supply output voltage reaches a preset limit on the "VP" device. The over-voltage protector device (VP) has the following specifications:
1) RANGE: 3V DC – 75V DC (adjustable).
2) TRIGGERING TIME: 5 to 10 microseconds, adjustable by means of a delay-control.
3) THRESHOLD: Overvoltage device may be set to within 5% or 0.25 volts of the power supply's output voltage (whichever is greater).

*Knob controlled on all metered models (suffix "M"), locking type screw-driver controls on unmetered models.

## 1-13 SPECIFICATIONS, PHYSICAL (Refer to FIG. 1-3, MECHANICAL OUTLINE DRAWING)

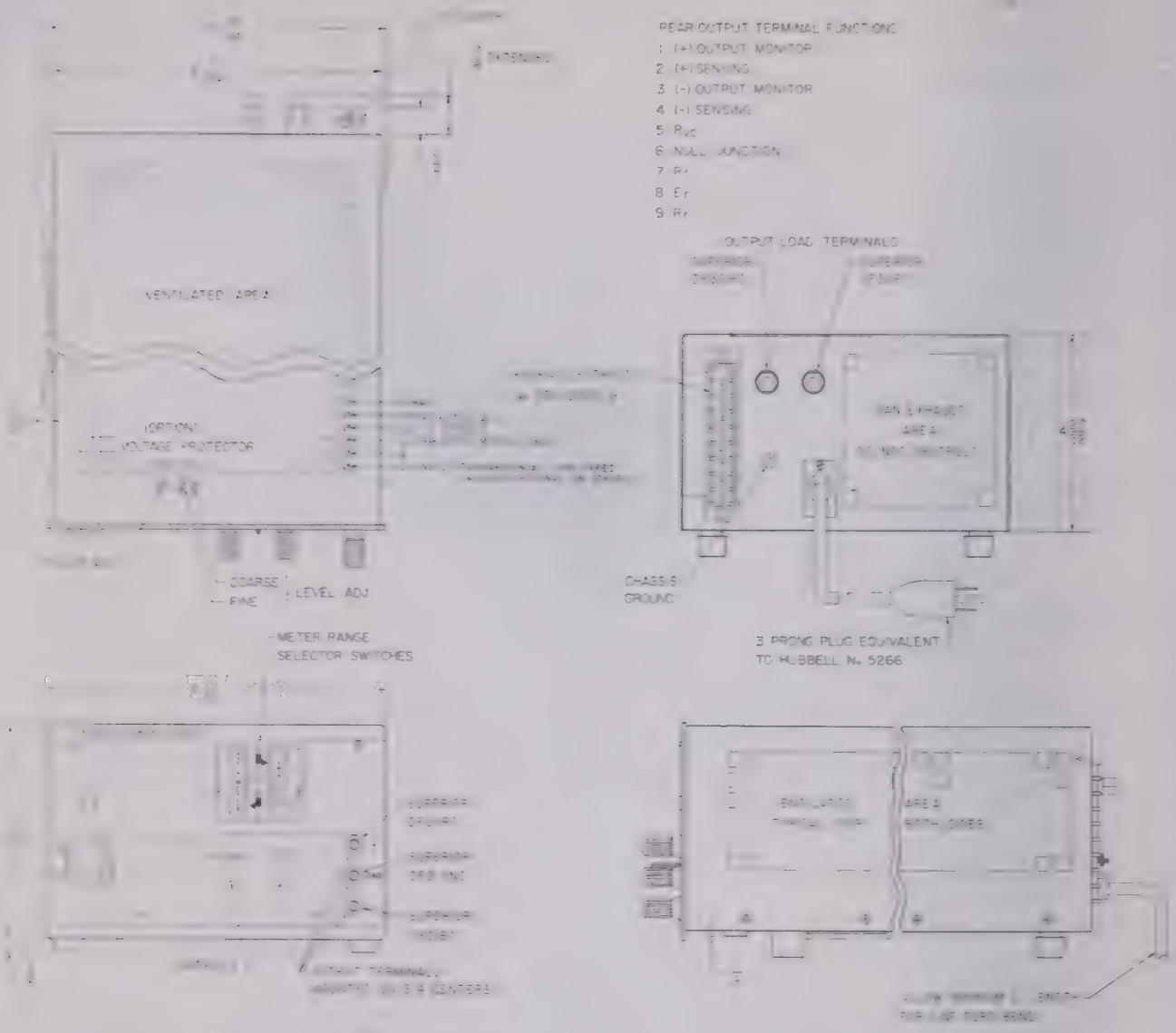
a) DIMENSIONS: (cased unit) "Half Rack": 5 1/4" H, X 8 11/32" W X 18 1/2" D (behind panel).

b) TERMINATIONS: Refer to Mechanical Outline Drawing (FIG. 1-3) and Section II of this manual.

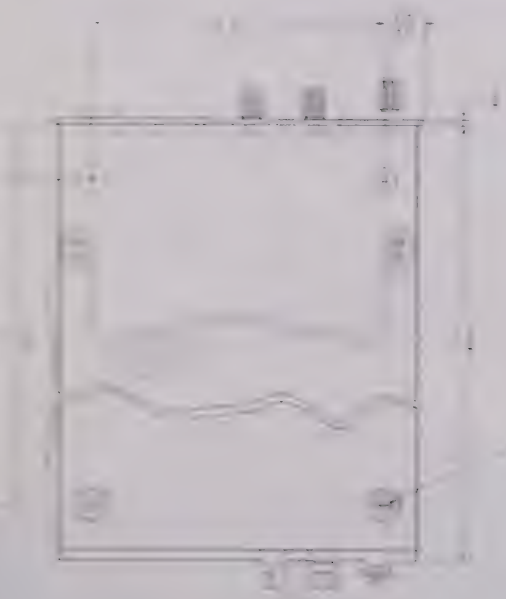
c) FINISH:
1) CHASSIS: cadmium plated, cronak wash.
2) PANEL (on models with suffix "M" only): Light gray, Color #26440, Federal Standard 595.
3) CASE: Charcoal gray texture.

d) METERS (on model with suffix "M" only): Two dual range (100% and 10% of $E_o$ max. and $I_o$ max.) 2 inch recessed panel meters, accuracy 3% of full scale reading, for output voltage and output current monitoring.

e) MOUNTING: Rack adaptor available, see "Accessories" (paragraph 1-9). A retractable "bail" is provided to adjust the supply to a convenient viewing and operating angle on the bench.





NOTES

1. THIS DRAWING USED FOR MODELS JQE 6-22M, JQE 15-12M, JQE 25-10M, JQE 36-8M, JQE 55-5M, JQE 75-3M, JQE 100-2.5M, JQE 25-20M, JQE 36-15M, JQE 55-10M, JQE 75-8M, JQE 100-5M, JQE 150-1.5M, JQE 150-3.5M
2. FRONT PANEL TERMINALS ARE NOT AVAILABLE ON MODELS JQE 6-22M, JQE 25-20M
3. MATERIAL A. COVER #18 GAUGE C.R.S.
   B. FRONT PANEL 1/8" THICK ALUMINUM
   C. CHASSIS #14 GAUGE C.R.S.
4. FINISH A. COVER CHARCOAL GRAY VINYL TEXTURE
   B. FRONT PANEL LIGHT GRAY [illegible] STD 595 COLOR #26440
   C. CHASSIS CADMIUM PLATE WITH A CHROMATE WASH
5. RACK MOUNTING REMOVE HANDLE, 12" REAR FEET AND FRONT RAIL

JQE MOUNTING SCREWS
8-16 x 5/8 FLAT HD. PHILLIPS
THREAD CUTTING
EQUIVALENT TO TYPE 25

FIG. 1-3 MECHANICAL OUTLINE DRAWING

# SECTION II – INSTALLATION

## 2-1 UNPACKING AND INSPECTION

2-2 This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in paragraph 2-8 below. If any indication of damage is found, file an immediate claim with the responsible transport service.

## 2-3 TERMINATIONS

a) FRONT PANEL: Refer to FIG. 2-3 and TABLE 2-2.
b) REAR: Refer to FIG. 2-4 and TABLE 2-3.
c) INTERNAL ADJUSTMENTS AND CALIBRATIONS: Refer to FIG. 2-1 and TABLE 2-1.

| REFERENCE DESIGNATION | CONTROL | PURPOSE | ADJUSTMENT PROCEDURE |
|---|---|---|---|
| C403* | Delay Adjust | Adjusts Delay Time of VP | par. 3-6 |
| R4 | $I_b$ Adjust | Control Current Calibration | par. 3-12 |
| R14* | $E_{io}$ Null Adjust | Output Voltage Precision Zero | par. 3-12 |
| R16,R36 | Lag Adjust | AC Stability Adjustment | par. 5-4 |
| R19 | $I_o$ max. Adjust | Current Limit Control Cal. | par. 5-4 |
| R414* | V Limit Adjust (Fine) | Adjusts Output Voltage Limiting | par. 2-8 |
| R415* | V Limit Adjust (coarse) | Adjusts Output Voltage Limits | par. 2-8 |

*NOTE: Optional controls, see paragraph 1-7.

TABLE 2-1 INTERNAL ADJUSTMENTS

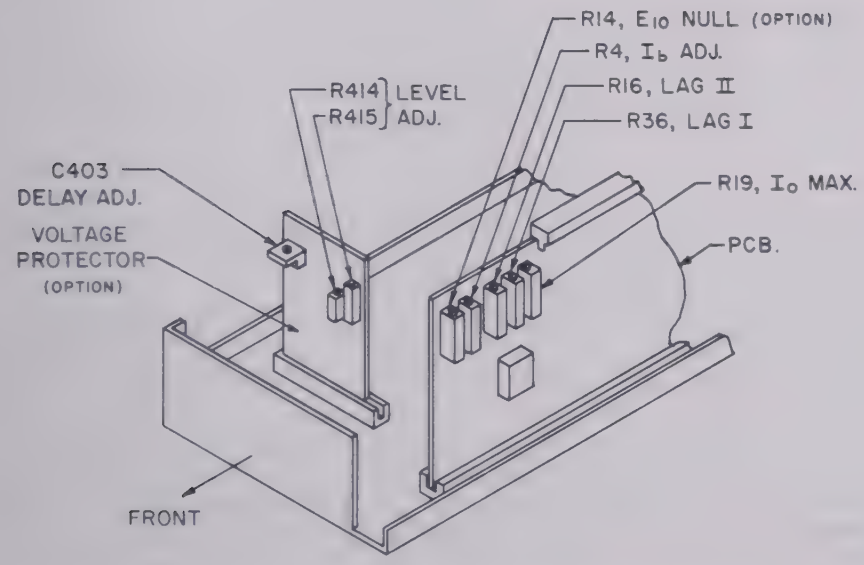



FIG. 2-1 LOCATION OF INTERNAL ADJUSTMENTS (NOT APPLICABLE TO "–HS" MODELS)

## 2-4 AC INPUT REQUIREMENTS

2-5 This power supply is normally supplied for operation on a single phase, nominal 115V AC line. For conversion to 230V AC line operation, refer to FIG. 2-2. Remove the two wire jumpers between transformer terminals indicated. Re-connect one (1) jumper between terminals indicated. Do not change any other wiring on the transformer. Change main fuse value (F201) to 1/2 its former rating.

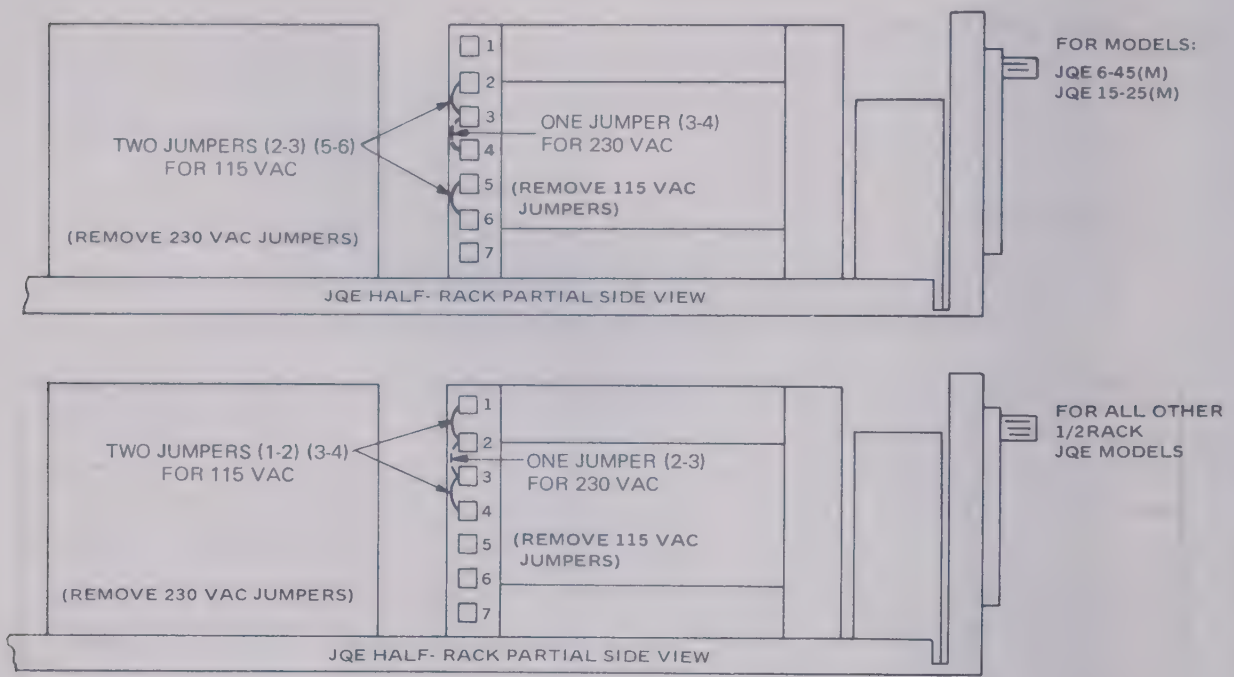



FIG. 2-2 CONVERSION TO 230V AC LINE OPERATION

## 2-6 COOLING

2-7 The power transistors and rectifiers in this power supply are maintained within their operating temperature range by means of a high efficiency heat-sink assembly, cooled by an internal fan. SIDE PANEL OPENINGS AND THE TOP OF THE CASE MUST BE KEPT CLEAR FROM OBSTRUCTIONS TO INSURE PROPER AIR CIRCULATION. Periodic cleaning of the interior of the power supply is recommended. If the power supply is rack mounted, or installed into confined spaces, care must be taken that the ambient temperature does not rise above the limit specified (Refer to Section I).

## 2-8 PRELIMINARY CHECK-OUT

2-9 A simple operating check after unpacking and before permanent installation is advisable, to ascertain whether the power supply has suffered damage resulting from shipment. Please refer to FIGS. 2-3, 2-4 for the location of the operating controls and output terminals.

a) Connect power supply to 115V AC line or refer to paragraph 2-4 for 230V AC operation if required.

b) Turn CURRENT LIMIT CONTROL full clockwise. Turn VOLTAGE CONTROL fully counter clockwise. Both, VOLTMETER RANGE* and AMMETER RANGE* switch should be in the "x1" position..

c) Turn AC POWER SWITCH "on". The AC PILOT LIGHT* should be energized. Slowly turn VOLTAGE CONTROL clockwise and observe the gradual increase of the output voltage. Turn counter clockwise again until about one tenth of the maximum output voltage is reached. Set VOLTMETER RANGE switch* to the "x0.1" positions.** The VOLTMETER* should now read full scale again. Turn AC POWER SWITCH "off".

* AC pilot light, range switches and metering provided on models with suffix "M" only. Connect appropriate external metering to meterless models.

** See note following paragraph 2-9e.

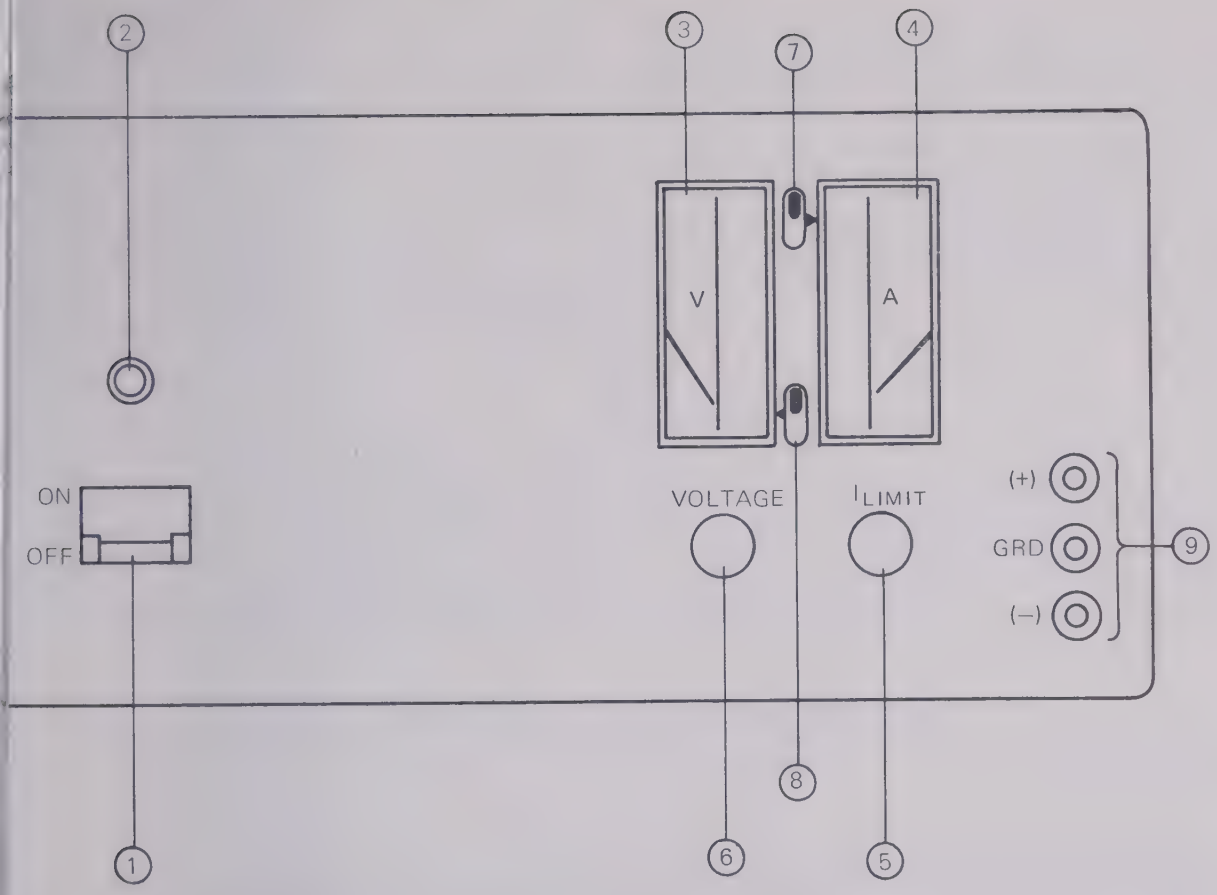
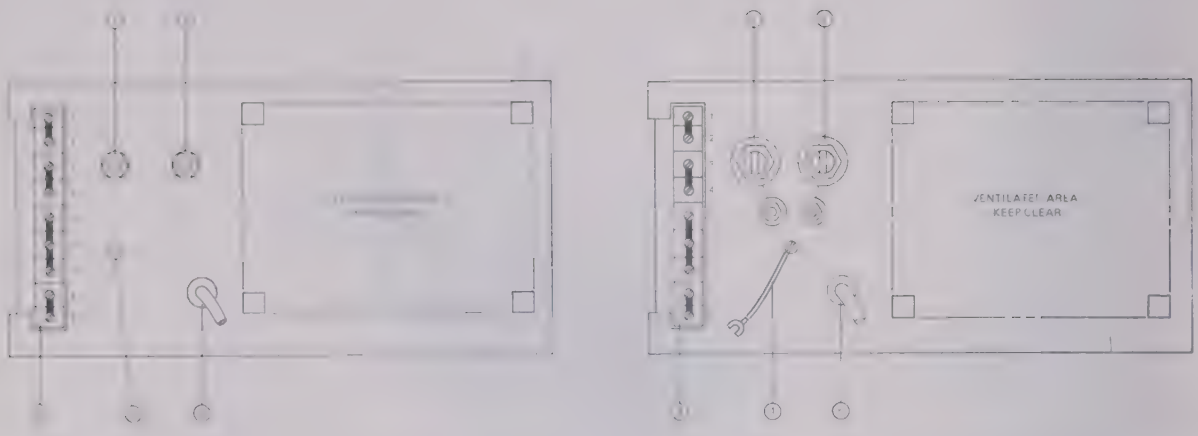



FIG. 2-3 FRONT PANEL CONTROLS AND TERMINATIONS,HALF–RACK JQE MODELS

| NO. | CONTROL OR TERMINATION | FUNCTION |
|---|---|---|
| 1 | AC POWER SWITCH/ CIRCUIT BREAKER | TURNS AC POWER LINE, "ON" OR "OFF" AND PROTECTS POWER SUPPLY INPUT CIRCUITRY |
| 2 | AC PILOT LIGHT | ENERGIZES WHEN AC POWER IS "ON" |
| 3 | VOLTMETER | MONITORS OUTPUT VOLTAGE, O-$E_o$ max. |
| 4 | AMMETER | MONITORS OUTPUT CURRENT O-$I_o$ max. |
| 5 | CURRENT LIMIT CONTROL | ADJUSTS CURRENT LIMIT FROM O-105% $I_o$ max. |
| 6 | VOLTAGE CONTROL | ADJUSTS OUTPUT VOLTAGE FROM ZERO TO $E_o$ max. |
| 7 | METER RANGE SWITCH, AMPERE | MAY BE SET TO FULL SCALE READING OF MAXIMUM OR 1/10 OUTPUT |
| 8 | METER RANGE SWITCH, VOLTS | MAY BE SET TO FULL SCALE READING OF MAXIMUM OR 1/10 OUTPUT |
| 9 | FRONT OUTPUT TERMINALS | FOR LOAD CONNECTION (ON MODELS WITH 15A DC OUTPUT AND LOWER ONLY) |

TABLE 2-2 CONTROLS AND TERMINATIONS,HALF–RACK JQE MODELS,FRONT




a) MODELS WITH LESS THAN 25A DC OUTPUT CURRENT

b) MODELS WITH 25A DC AND 45A DC OUTPUT CURRENT

**FIG. 2-4 REAR TERMINATIONS, HALF-RACK METERED MODELS**

| NO. | TERMINATION | FUNCTION |
|---|---|---|
| 1 | (−) OUTPUT | *NEGATIVE LOAD TERMINAL WITH GROUNDING POST |
| 2 | (+) OUTPUT | *POSITIVE LOAD TERMINAL WITH GROUNDING POST |
| 3 | REAR BARRIER STRIP | PROGRAMMING AND MONITOR TERMINALS |
| | | (1) (+) OUTPUT MONITOR |
| | | (2) (+) ERROR SENSING |
| | | (3) (−) OUTPUT MONITOR |
| | | (4) (−) ERROR SENSING |
| | | (5) INTERNAL VOLTAGE CONTROL |
| | | (6) NULL JUNCTION (AMPLIFIER INPUT) |
| | | (7) REFERENCE RESISTOR |
| | | (8) REFERENCE VOLTAGE |
| | | (9) REFERENCE RESISTOR |
| 4 | CHASSIS CONNECTION | *FLOATING GROUND LEAD TO GROUND EITHER (+) OR(−) OUTPUT VIA GROUND POST |
| 5 | AC INPUT | 3 WIRE SAFETY LINE CORD |

**TABLE 2-3 REAR TERMINATIONS, HALF-RACK METERED MODELS**

*MODELS WITH LESS THAN 25A DC OUTPUT CURRENT (FIG. 2-4a) DO NOT HAVE GROUNDING POSTS. THE CHASSIS CONNECTION ON THESE MODELS IS A TERMINAL INSTEAD OF A FLOATING GROUND LEAD.

d) (Models suffixed "-VP" only) Check the "crowbar" action of the overvoltage protector by first adjusting the VOLTAGE CONTROL to about one quarter of the rated output voltage. Locate the "$V_{limit}$" adjustments (R414,415,refer to FIG. 2-1) and turn the "Coarse" adjustment (R415) slowly counter clockwise until the output voltage goes suddenly to zero as ovserved on the panel meter. Turn AC POWER SWITCH "off". Turn the coarse "$V_{limit}$" control (R415) fully clockwise again.

e) Place a short circuit across the output.* Turn CURRENT LIMIT CONTROL counter clockwise. Turn AC POWER SWITCH "on". Slowly turn CURRENT LIMIT CONTROL clockwise and observe the gradual increase in output current. Turn counter clockwise until about one tenth of the maximum output current is reached. Set AMMETER RANGE switch to the "x0.1" position. The AMMETER should now read full scale again.

* CAUTION

1) DO NOT SWITCH TO THE "X0.1" RANGES BEFORE THE OUTPUT OF THE POWER SUPPLY (VOLTAGE OR CURRENT) IS BELOW 10% OF THE MAXIMUM RATED VALUES.
2) CONNECT SHORT CIRCUIT (OR LOAD) TO THE HEAVY DUTY OUTPUT TERMINALS, NOT TO THE BARRIER STRIP. BARRIER STRIP TERMINALS ARE FOR VOLTAGE MONITORING AND PROGRAMMING CONNECTIONS ONLY.

## 2-10 INSTALLATION (Refer to FIG. 1-3 "Mechanical Outline Drawing")

2-11 The metered JQE Power Supply (Models with suffix "M") may be used as a bench-operated instrument. For these units, a retractable "bail" is provided to lift the power supply front to a convenient viewing and operating angle. If the metered JQE supply is to be rack-mounted, the bail, the two rear feet and the side handles must be removed.

2-12 The unmetered JQE Power Supply can be directly chassis-mounted into any system. Four nylon mounting stand-offs are provided at the bottom of the unit. If no additional mechanical support is provided, the unit must always be mounted so that its weight rests on the four mounting stand-offs.

2-13 For all installations into confined spaces, care must be taken that the temperature immediately surrounding the unit does not exceed the maximum specified ambient temperature (71°C).

## 2-14 GROUNDING

a) AC GROUND (Models with suffix "M" only). The power supply is equipped with a 3 wire safety line cord and polarized plug. The third (green) wire in the line cord is connected to the chassis and the case of the unit. If a two terminal receptacle in combination with an adaptor is used, it is imperative that the chassis of the power supply be returned to AC ground with a separate lead.

b) AC GROUND (Unmetered Models). The power supply is equipped with a three terminal barrier strip for AC input. The terminal marked "GRD" is directly connected to the power supply chassis and must be returned to AC ground.

c) DC GROUND. The DC output is isolated from the AC power line and from any direct connection to chassis or ground.* The maximum voltage that can be supported between either output terminal and ground or chassis is 500V DC plus the maximum output voltage of the power supply. Either side of the output may be grounded. Convenient grounding terminals are provided at the front panel binding post and the rear barrier strip.

*A capacitor-resistor network (C5, R25) is connected from the negative (−) output terminal to chassis. If the output is to be grounded externally, this internal ground can be opened by removing C5 from the amplifier board (A1, see FIG. 6-2).

# SECTION III – OPERATION

## 3-1 STANDARD POWER SUPPLY OPERATION, LOCAL CONTROL

3-2 GENERAL. The Power Supply is shipped from the factory with five (5) removable jumper links in place at the rear barrier strip (TB501) as shown in FIG. 3-1. THESE LINKS MUST BE IN PLACE AND SECURED TIGHTLY for standard local operation. Loose terminal links or wires at the barrier strip will cause malfunction of the power supply.

3-3 LOAD CONNECTION The load may be connected in any of the two ways illustrated (FIG. 3-1,3-2). Load connecting wires should be as heavy as practicable, since load wire voltage drops will degrade regulation performance. Twisting of load wires will help to preserve the low output impedance of the power supply. To keep the DC voltage drop in the load connecting wires to a minimum, and to preserve the dynamic characteristics of the power supply (AC stability, output impedance and recovery time), load wires and error sensing leads should be as short and as large in diameter as practicable. Both lead pairs should preferably be tightly twisted. For minimum ripple and noise pick-up, the error sensing leads must be shielded. The shield, as well as one side of the output (preferably the positive), should be returned to the common ground point (Refer to FIG. 3-2).

**CAUTION**

THE LOAD MUST BE CONNECTED TO THE HEAVY DUTY OUTPUT TERMINALS AT THE REAR, NOT TO THE BARRIER STRIP. BARRIER STRIP TERMINALS ARE FOR MONITORING AND PROGRAMMING PURPOSES ONLY.

## 3-4 REMOTE ERROR SENSING

3-5 Specified regulation performance DIRECTLY AT THE LOAD requires the use of remote error sensing. A twisted, shielded pair of wires from the sensing terminals directly to the load will compensate for load wire voltage drops up to 0.5 volt per wire (Refer to FIG. 3-2). Observe polarities: The positive sensing wire [from terminal (2)] goes to the positive load wire.

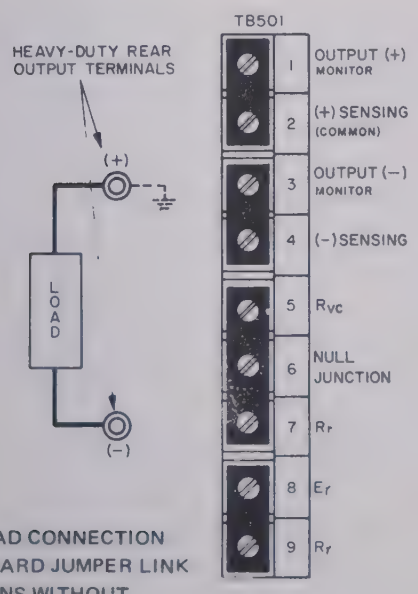



FIG.3-1 LOAD CONNECTION AND STANDARD JUMPER LINK CONNECTIONS WITHOUT ERROR SENSING

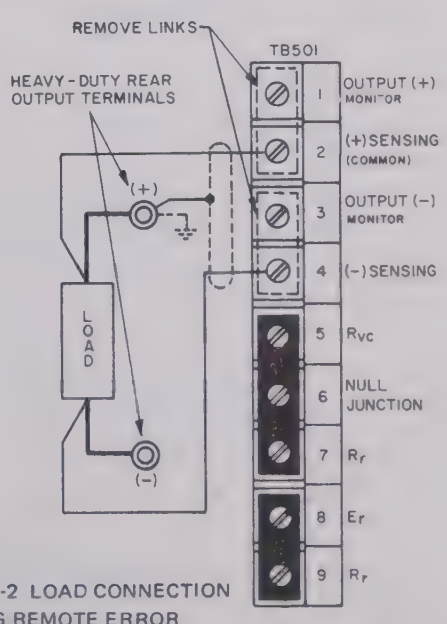



FIG. 3-2 LOAD CONNECTION USING REMOTE ERROR SENSING

## 3-6 OUTPUT ADJUSTMENT (Refer to FIG.'s 2-1 and 2-3 for the location of all controls)

3-7 a) Once the load is connected to the output terminals of the power supply as described in the previous paragraphs, the operating voltage may be adjusted to the desired value by turning the VOLTAGE CONTROL and observing the panel VOLTMETER.* The CURRENT LIMIT CONTROL may be set fully clockwise, and will in this position provide over current protection at 105% of the maximum rated output current. The CURRENT LIMIT CONTROL may also be set to intermediate values, as desired, by first turning the AC POWER SWITCH to the "off" position and then placing a short circuit across the output. Turn AC line "on". Now the required operating current is adjusted by turning the CURRENT LIMIT CONTROL to the value needed plus ≈ 2%. The output current will now limit sharply at this value. After the short is removed from the output, the voltage protector can be set.

b) (For Models equipped with Voltage Protector only.) With the "V Limit" control set fully clockwise, set the output voltage as described above. Turn the coarse "V Limit" control** (R415) slowly counter clockwise, until the power supply output "crowbars", indicated by the output voltage going to zero and the circuit breaker shutting off. Turn the fine "V Limit" control (R414) slightly clockwise. The amount of "threshold" or difference voltage between operating voltage and the limiting point, is determined by this last adjustment, which should therefore be made with the "fine" control, R414. A too close adjustment towards the operating voltage may lead to spurious triggering, especially if the "delay" adjustment is set for maximum sensitivity. The minimum "threshold" voltage adjustable is 0.5 volt.) Adjust the "delay" capacitor (C413) if required. This control is factory adjusted for maximum sensitivity, consistent with reliable operation without spurious triggering. It needs re-adjustment only if extremely sensitive loads must be triggered in the shortest time possible and if some spurious triggering can be tolerated. Now the load can be connected to the power supply and operation can commence.

*Use external metering for meterless models.

**If model has only a "fine" control (R414), all VP Adjustments are made with this control.

## 3-8 INTRODUCTION TO REMOTE PROGRAMMING

3-9 GENERAL. A few general remarks may be in order to familiarize the user of this equipment with the terminology and basic equations pertaining to remote programming of Kepco Power Supplies. Electrically, the power supply, consists of the unregulated DC source ($E_u$), the pass element ($E_p$), the DC error amplifier (A) and a comparison circuit which resembles a four-arm electrical bridge. (Refer to FIG. 3-3). The elements of the bridge are arranged to produce a virtual zero at the amplifier input when the bridge circuit is at balance ($V_{AA'} = 0$). Any tendency for the output voltage to change in relation to the reference voltage ($E_r$) creates an error signal ($\epsilon$) which, by means of negative feedback and the amplifier, tends to correct the output voltage towards restoration of bridge balance.

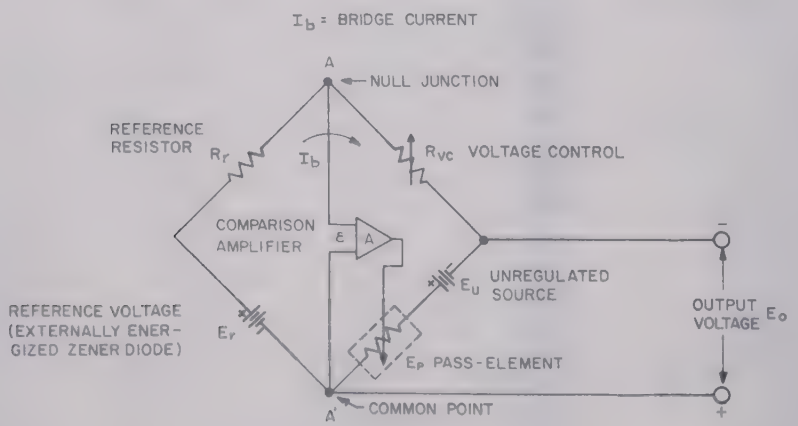



FIG. 3-3 KEPCO POWER SUPPLY CIRCUIT WITH COMPARISON BRIDGE (SIMPLIFIED)

## 3-10 EQUATIONS SHOWING THE OPERATION OF THE KEPCO BRIDGE

3-11 The following relationships govern the operation of the Kepco Bridge at balance, i.e., with $V_{AA'} = 0$:

a) $\frac{E_o}{E_r} = \frac{R_{vc}}{R_r}$ (1)

$\frac{E_r}{R_r} = I_b$ (2)

$E_o = I_b R_{vc}$ (3)

Where: $E_o$ = Output Voltage
$E_r$ = Reference Voltage
$R_r$ = Reference Resistance
$R_{vc}$ = Control Resistance
$I_b$ = Bridge or Control Current

b) The ratio of the number of ohms control - resistance needed per volt output is termed the "CONTROL RATIO". It is normally 1000 ohm/volt in KEPCO Power Supplies.

c) As can be seen from equation (1), the output voltage $E_o$ can be controlled by varying any one of the three quantities. Rewriting equation (1) we have:

$$E_o = \frac{E_r}{R_r} \times R_{vc}$$

The ratio $\frac{E_r}{R_r}$ constitutes the bridge or control current $I_b$. (Eq. 2).

d) Therefore, we can write: $E_o = I_b R_{vc}$ (Eq.3).
Making $I_b$ a precision quantity (precision bridge current adjustment is described in par. 3-16), establishes a precise programming ratio, so that the accuracy of $E_o$ is solely dependent upon $R_{vc}$. This mode of operation is referred to as "RESISTANCE PROGRAMMING" and is covered in detail in Par. 3-19.

e) Rewriting equation (1), $E_o = E_r \frac{R_{vc}}{R_r}$, we can make $E_r$ the variable which controls $E_o$.

This type of control is refered to as "VOLTAGE PROGRAMMING" and is covered in Par. 3-25.

f) Many other modes of control are of course possible, some of them are described in the following paragraphs. For a more extensive treatment and a detailed theoretical view of power supply applications see the "Kepco Power Supply Handbook", available from your Kepco Representative or directly from Kepco Applications Engineering Department.

NOTE: For all programming and adjustment components, use high quality, wire-wound, resistors with a T.C. of 20 p.p.m. or better.

## 3-12 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO*

3-13 Referring to equation (3): $E_o = I_b R_{vc}$, it is seen that if $I_b = 1$ mA, 1000 ohms of control resistance ($R_{vc}$) is needed for each volt of output. Making $I_b$ therefore a precision quantity the accuracy and linearity of the output voltage will then solely depend upon $R_{vc}$.

3-14 Again refering to equation (3), we see that if $R_{vc} = 0$ (shorted out), the output voltage should be zero. A small negative offset voltage (in the millivolt range) exists however under this condition at the output.

3-15 Both inaccuracies, the slightly larger bridge current ($I_b$) and the small negative offset voltage ($E_{io}$) may be adjusted to provide a linear and precise programming ratio. Refer to FIG. 2-1 for the location of the calibration controls.

3-16 PROCEDURE. PRECISION PROGRAMMING RATIO ADJUSTMENT (Refer to FIG. 3-4)

a) Equipment Required:
1) Precision digital or differential voltmeter (M1).
2) Precision resistor, accuracy comparable to M1. The value is not important, but must be known. For every 1000 ohms, 1 volt will appear across M1. ($R_{vc}$).
3) Single pole, single throw switch (S1).

*Applicable for models with suffix "E" only.

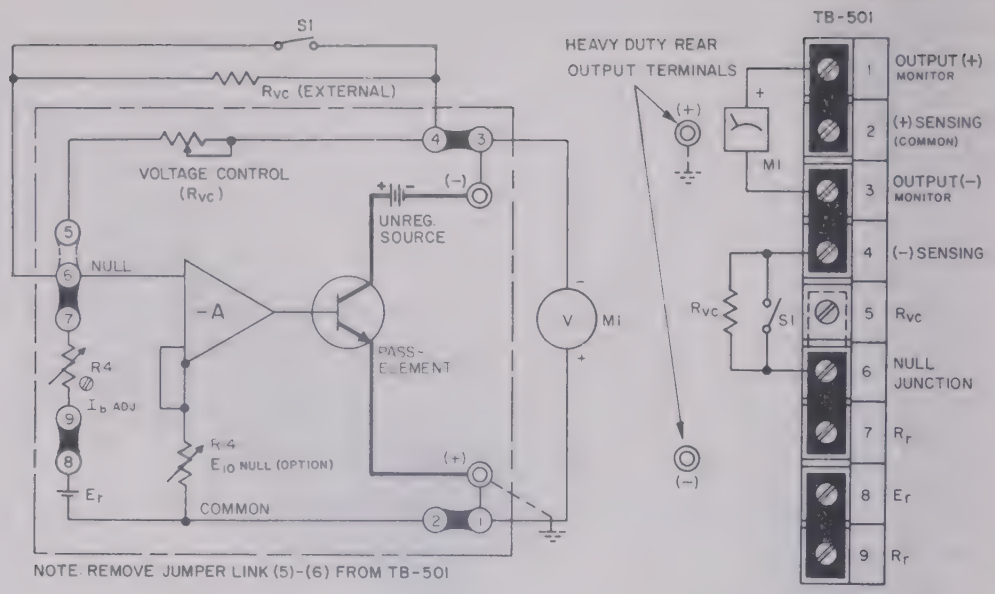



FIG. 3-4 CONNECTIONS FOR PRECISION PROGRAMMING RATIO ADJUSTMENT

b) Connect calibration set-up as shown in FIG. 3-4 and connect the power supply to the AC power line.

c) With S1 "open", and $R_{VC}$ = 5 K ohms, approximately 5 volts will be read-out on M1. Adjust R4 (Ib adjustment) until exactly 5 volts are read-out on M1.

d) Close S1 and note deviation from zero on M1 (approx. 2 to 8 mV negative). Adjust R14 (zero adjustment) until exactly zero volts read-out on M1.

e) Open S1 and check the 5 volt reading. Repeat "c" and "d" as necessary to achieve the desired accuracy. FIG. 3-5 below shows graphically how the programming ratio can be precision adjusted.

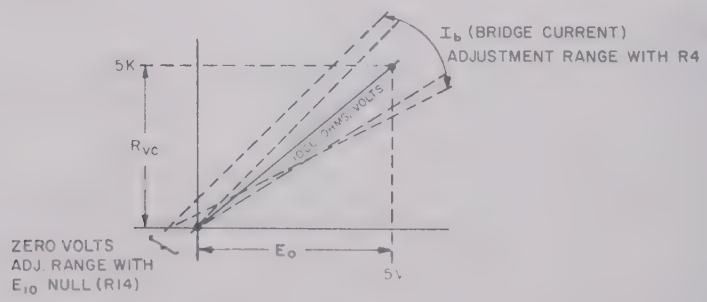



FIG. 3-5 ESTABLISHING PROGRAMMING LINEARITY

## 3-17 GENERAL RULES FOR REMOTE PROGRAMMING

3-18 All remote programming applications require the observance of a few basic rules to insure proper functioning of the power supply in the particular mode of operation selected. These rules should be remembered before each application and especially if malfunctioning of the programming set-up is experienced.

1) GROUNDING. Ground loops due to multiple and indiscriminant grounding of various equipment are the cause of the majority of complaints about "high ripple or noise". They can be easily avoided by grounding the power supply at one point only to which all shielded cables and equipment cases are connected. If possible, one side (preferable the positive one) of the power supply output should also be grounded. Frequently, high ripple is introduced by programming sources or instruments used at the input (null junction) although all grounding rules have been observed. This may be due to the external instruments or source's close coupling to the AC line. In these cases only isolation (i.e. battery operated devices) is the answer. It must also be remembered that input and output of the power supply are "common", so that if the output is not grounded, the input source must be isolated for the maximum output voltage to be programmed, plus the amount of voltage the common is "off ground".
2) CONNECTIONS. All external connections, especially the rear barrier strip terminal screws, must be tight. Series malfunctions may be caused by open feedback loops or programming connections.
3) INPUT SOURCES. If specified performance is expected when remote programming, external input or reference sources must have specifications equal to or better than that of the power supply.
4) PROGRAMMING RESISTORS Programming resistors should be high quality wirewound units with temperature coefficients of 20 parts per million or better. Their wattage rating must be at least 10 times the actual power dissipated. Although the control current through these resistors is only 1 mA, an error current exists when programming large voltage excursions. The magnitude of this error current equals the change in output voltage, divided by the final resistance of the programming resistor. (If, for example, the voltage step is from 50 volts to zero, ($\Delta E_o = 50$ V) and the final resistance of the programming resistor is $\Delta R_{vc} = 2$ ohms, $I_{peak} = 25$ A. The duration of the peak error current depends upon the size of the output capacitor. $I_{peak}$ decays exponentially as the output voltage assumes the final value.
5) EXTERNAL SWITCHING. If step-switch devices are used in resistance programming, they must be of the "make before break" variety to avoid programming infinity. Programming resistors must have a voltage rating at least equal to the maximum output voltage of the power supply.

## 3-19 OUTPUT VOLTAGE PROGRAMMING WITH EXTERNAL RESISTANCE

The output voltage of the Power Supply may be controlled remotely by an external resistance, replacing the built-in voltage control resistance which is disconnected at the rear barrier strip. The value of the programming resistance may be calculated by referring to the transfer function derived earlier (Eq.1):

$$E_o = R_{vc} \times \frac{E_r}{R_r}$$

Since $\frac{E_r}{R_r} = I_b$ (2), it follows that $E_o = I_b R_{vc}$ (3)

Referring to Equation (3), we see that since $I_b$ is 1 mA in KEPCO Power Supplies (and can be precisely adjusted as shown in Par. 3-12), for every volt of output, 1000 ohms control resistance must be provided. This corresponds to a "Programming Ratio" of 1000 ohms per volt.

3-20 PROCEDURE (Refer to FIG. 3-6)

a) Determine value of programmin resistor(s) for output voltage desired.
b) Using two-wire, shielded cable, connect the chosen resistors to terminals (4) and (6). Connect the shield to the "ground" terminal.
c) The output voltage will vary from zero to (1 mA) x ($R_{vc}$), as $R_{vc}$ is adjusted from zero to its maximum value.

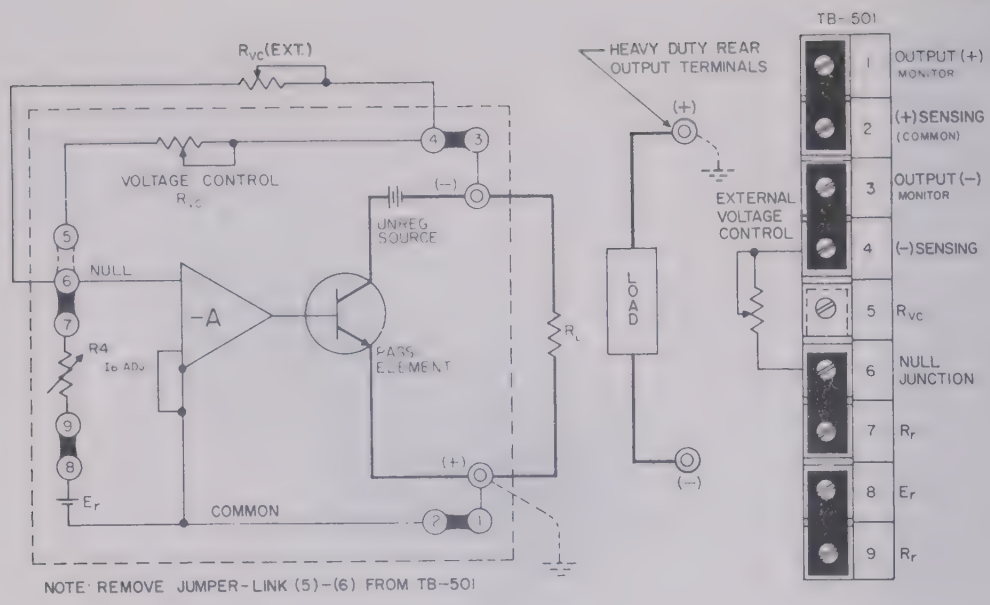



FIG. 3-6 REMOTE RESISTANCE PROGRAMMING

### 3-21 PROGRAMMING BY CONDUCTANCE:

3-22 For special applications, the output voltage $E_o$ can be adjusted by varying the bridge current. The relationship governing this type of programming is:

$$E_o = E_r\ (R_{VC})\ (G), \quad \text{(Eq. 4)} \qquad \text{Where:} \quad G = \frac{1}{R_r + R_x} = \text{programming conductance}$$

or

$$E_o = \frac{E_r}{R_r + R_x} \times (R_{VC})$$

$E_o$ = output voltage
$E_r$ = reference voltage
$R_{VC}$ = control resistance
$R_r$ = reference resistance
$R_x$ = programming resistor

Since $\frac{E_r}{R_r} = I_b$ and $E_o = I_b R_{VC}$, the output voltage varies directly as $I_b$ changes. Changing $I_b$ with the help of an additional resistor in series with $R_r$ results in an inversely proportional change of $I_b$, since now

$$I_b = \frac{E_r}{R_r + R_x}$$

This method of output voltage adjustment is therefore referred to as conductance programming.

3-23 Conductance programming is a reciprocal function when analyzed in terms of resistance, but perfectly proportional

$$E_o \propto \frac{1}{R_x}$$

It can be very useful, expecially over a limited range and for small changes in output voltage. Another distinctive advantage of this type of programming is the "built-in" safety feature. Should the programming circuit open accidently, the programming resistance becomes infinite, the conductance is zero, and consequently, the output voltage becomes zero.

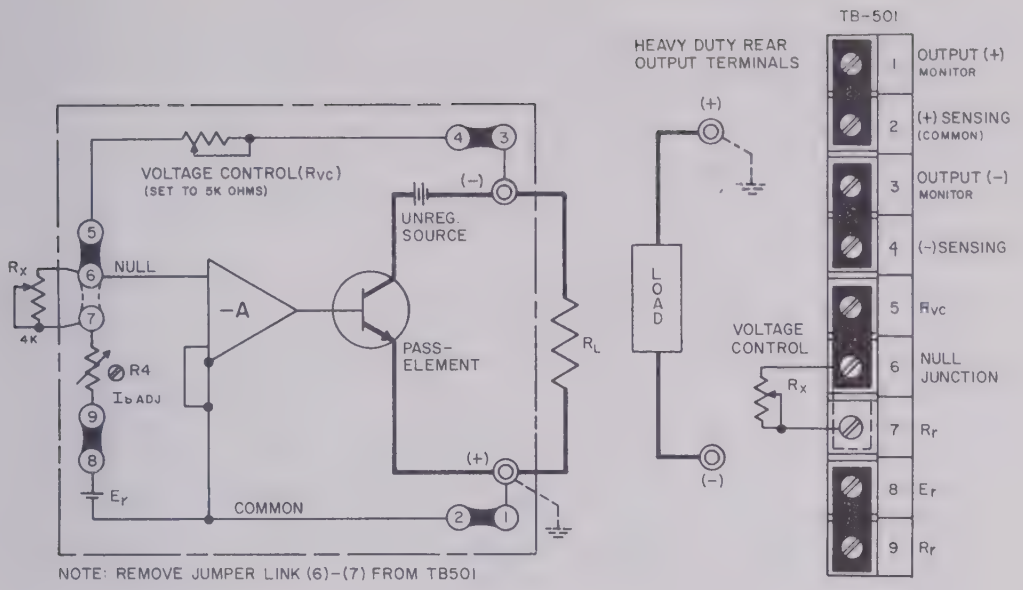



FIG. 3-7 REMOTE CONDUCTANCE PROGRAMMING

3-24 PROCEDURE (Refer to FIG. 3-7)

EXAMPLE: $E_o$ desired = 3 to 5 volts.

a) Select $R_{vc}$ for maximum desired output voltage $E_o$.

$$R_{vc} = \frac{E_o}{I_b}\ ;\ R_{vc} = \frac{5V}{1\ mA} = 5\ K\ ohms.$$

Set built in $R_{vc}$ to 5 K ohms, or disconnect and use external resistor.

b) A change of $E_o$ to 3 volts requires a bridge current change of:

$$\Delta I_b = \frac{\Delta E_o}{I_b} = \frac{2\ volts}{5\ K\ ohms} = .4\ mA$$

c) Since $I_b = \frac{E_r}{R_r} = 1$ mA, the additional resistance needed is:

$$I_b\ (R_r + R_x) = E_r;\ R_x = \frac{E_r}{I_b} - R_r \text{ or } R_x = \frac{6\ volts}{0.6\ mA} - 6\ K = 4\ K\ ohms.$$

A 4K ohm, WW, low T.C. potentiometer, connected as shown in FIG. 3-7, will change the output voltage from 3 to 5 volts when varied from zero to 4K ohms.

NOTE: A word of caution may be in order in regard to the changing of the bridge current. The 1 mA value has been selected for maximum stability in the zener reference circuit. A large departure from this value is not advisable. If a ±50% change in $I_b$ is not sufficient to achieve the desired voltage swing, an external reference supply can be used.

## 3-25 REMOTE PROGRAMMING WITH EXTERNAL CONTROL VOLTAGE

3-26 The output voltage of KEPCO power supplies may be controlled by an external, variable voltage source, which supplies the necessary control current, formerly delivered by the (now disconnected) internal, fixed reference source. This mode of operation is termed "Voltage Programming". It can be mathematically expressed by referring to basic equation (1):

$\frac{E_O}{E_r} = \frac{R_{VC}}{R_r}$ (Eq. 1) Solving for $E_O$, and designating the external programming components "$E_i$, $R_i$"

the result is: $E_O = -E_i \times \frac{R_{VC}}{R_i}$ (Eq. 5)

3-27 As seen from the expression (Eq.5), if the ratio $R_{VC}/R_i$ (which represents the closed loop gain of the system) is held constant, $E_O$ will vary linearly with $E_i$, the external programming voltage. The above expression (Eq.5) is seen to be similar to the operational amplifier transfer function in the inverting configuration. The voltage programmed power supply does in fact become a unipolar power amplifier with potentially very high power gain but with limited frequency response. (Refer to FIG. 3-8). The limited frequency response is largely due to the effect of the output capacitor ($C_O$) acting as a low-pass filter and preventing the output voltage ($E_O$) from varying rapidly. The output voltage may be varied over the full range, bounded on the high end by the maximum rated value. A practical example to illustrate component selection will be given below.

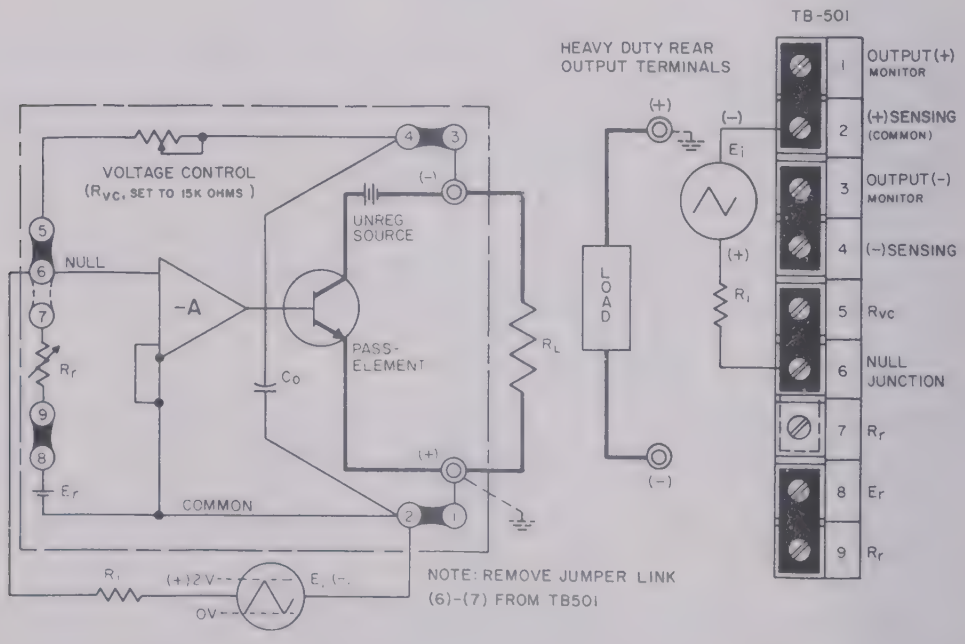



FIG. 3-8 THE POWER SUPPLY IN THE OPERATIONAL AMPLIFIER MODE

3-28 Example: A power supply with a rated maximum output voltage of 15 volts is to be voltage programmed over its full range (0 to 15V) by a triangular, positive increasing source with a peak output voltage ($E_i$) of 2 volts, and able to deliver at least 1 mA control current. Since the required voltage gain is: $E_O/E_i = 15/2 = 7.5$, the ratio $R_{VC}/R_i$ must also equal 7.5. If the internal voltage control is retained, in this case, since $R_{VC} = 15$ K ohms, $R_i$ must equal 15 K/7.5 = 2 K ohms. FIG. 3-8 shows the Power Supply as an operational amplifier and the necessary rear barrier connections for this mode of operation.

## 3-29 CONSTANT CURRENT OPERATION

3-30 A KEPCO power supply can be set up to deliver constant current by the addition of an external sensing resistor and a current control. In the constant current operating mode, the voltage comparison bridge is interconnected with an external current sensing resistor, $R_S$, and a current control, $R_{CC}$ (as shown in FIG. 3-9) to maintain a constant voltage drop across $R_S$. In this way, an adjustable constant load current is obtained. Characteristic of the constant current supply is ability to change its output voltage automatically in order to maintain a constant current through a range of possible load resistances. The range of output voltage that the supply can deliver and simultaneously maintain constant current, is referred to as the "COMPLIANCE VOLTAGE".

3-31 The current sensing resistor $R_S$ is chosen to develop a 0.5 volt drop at the maximum desired current.* It is calculated by dividing this current into 0.5 volt. The value of $R_S$ is not critical and can be the nearest standard resistance available. Several facts should be kept in mind however, when choosing $R_S$. A compromise must be made between a large and a small value. While a large value is desirable for good current regulation, it is less so in view of the power dissipated across it. It must be remembered that all the load current is flowing through $R_S$ and the input to the regulator is connected across it. It is therefore vital that all extraneous changes across $R_S$, i.e. resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20 PPM) resistor, at least ten times the actual wattage needed, is therefore strongly recommended. In practice, $R_S$ is usually selected for a 0.5 volt sample at maximum output current desired.* If more than a 10:1 ratio of output current is needed, several values of $R_S$ should be selected and switched in or out as required.

*For KEPCO Power Supplies with maximum rated output currents of 5 A DC or less, a 1 volt sample at the maximum desired current should be used.

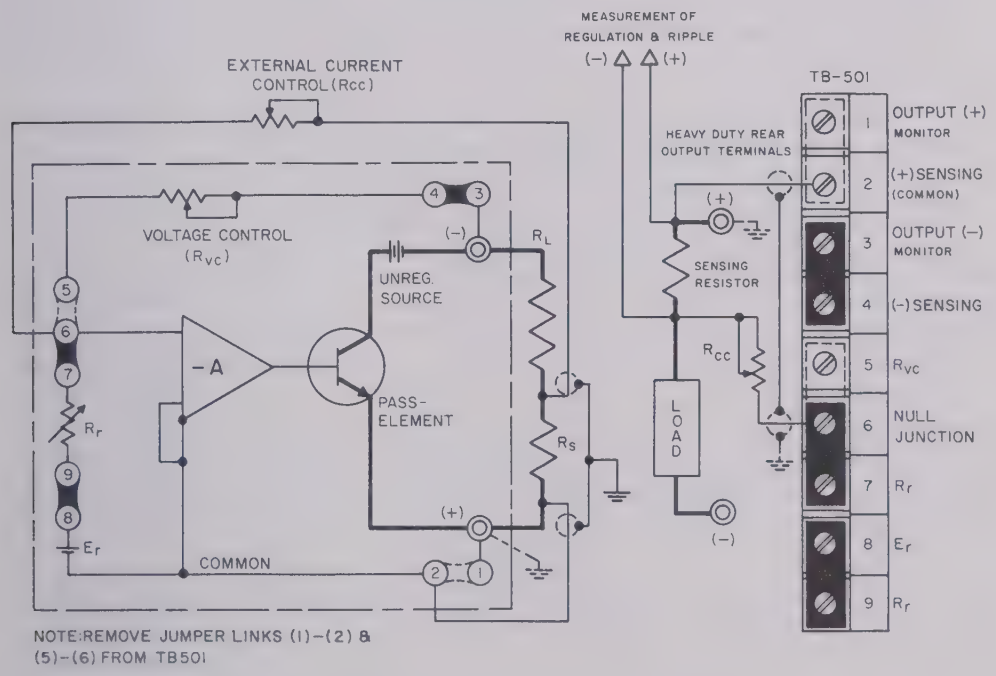



FIG. 3-9 CONSTANT CURRENT OPERATING MODE

3-32 The current control resistor, $R_{CC}$ is chosen on the basis of the control ratio of the Kepco comparison bridge, and $V_S$ the maximum voltage across $R_S$. If $R_S$ was selected for 0.5 volt drop, then $V_S$ = 0.5 volt and $R_{CC} = V_S$ times (control ratio), or

$$R_{CC} = 0.5 \text{ volt} \times \frac{1000 \text{ ohm}}{\text{volt}} = 500 \text{ ohms.}$$ A high quality, low T.C. (20 PPM) resistor is recommended for $R_{CC}$.

3-33 PROCEDURE (Refer to FIG. 3-9)

The actual component calculation for current regulation is perhaps best shown by a practical example. A KEPCO Power Supply with a rated maximum output current of 50 A DC is to be set up for current regulated output from 5A to 50A (1:10 ratio).

a) $R_S$ is chosen by: $R_S = \frac{0.5 \text{ volt}}{50 \text{ A}} = 0.01$ ohm.

$P_{diss} = V_S \times I_{max.} = 0.5 \text{ volt} \times (50 \text{ A}) = 25$ watts. (use 250 watt)

NOTE: A heavy duty, 4 terminal meter shunt or a power resistor in the TEPRO "TMK" series is required. Inquire at KEPCO if special values are needed.

b) The control resistance $R_{CC}$ is found by calculating its limits:

$$R_{CC} \text{ (max.)} = V_S \text{ (max.)} \times \text{control ratio} = 0.5 \text{ V} \times \frac{1000 \text{ ohms}}{\text{V}} = 500 \text{ ohms.}$$

$$R_{CC} \text{ (min.)} = V_S \text{ (min.)} \times \text{control ratio} = 0.05 \text{ V} \times \frac{1000 \text{ ohms}}{\text{V}} = 50 \text{ ohms.}$$

As $R_{CC}$ is therefore varied from 50 ohms to 500 ohms, the regulated current will vary from 5 to 50 mA. The compliance voltage will change in the same ratio (10:1), its absolute value depending on the load resistance used.

c) A large output current range (1 mA to 50 A) could be covered if three separate sensing resistors were to be calculated on the basis of a 0.5 volt sample at maximum current:

a) $R^1_S$ (For 5 to 50 A) = 0.5 V/50 A = 0.01 Ω (250 watt)
b) $R^2_S$ (For 0.5 to 5 A) = 0.5 V/5 A = 0.1 Ω (25 watt)
c) $R^3_S$ (For 0.05 mA to 0.5 A) = 0.5 V/0.5 A = 1 Ω (2.5 watt)

## 3-34 SERIES OPERATION OF KEPCO POWER SUPPLIES

3-35 GENERAL. Kepco Power Supplies can be series-connected for increased voltage output, provided the specified limits on voltage to chassis are not exceeded. When series-connected, the supplies should be protected by means of a semiconductor diode across the output terminals of each power supply, as shown in FIG. 3-10. The peak inverse rating of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the diodes should be at least as great as the largest short-circuit current of the interconnected supplies.

3-36 Two basic series connection methods are generally used, the "Automatic Series Connection", as illustrated in FIG. 3-10, and the "Master-Slave" connection, shown in FIG. 3-11. The basic difference between these two alternate methods lies in the manner of the output control. While in the "Automatic" connection the outputs of both supplies may be controlled individually, in the "Master-Slave" connection, control is exercised from the "Master" supply alone, while the "Slave" supply follows the master command in a ratio which may be pre-determined by the user. The latter method of series operation is therefore frequently termed "Automatic Tracking".

3-37 PROCEDURE FOR AUTOMATIC SERIES CONNECTION

a) Connect load as shown in FIG. 3-10. Keep voltage drop in load wires as low as practical by using heavy gauge wire.
b) Connect protective diodes across respective output terminals.
c) Remove jumpers as shown and connect error sensing leads. These leads should also be as heavy as practicable, and should be twisted and shielded.
d) Turn supplies on and adjust voltage on either control as required.

3-38 The "Master-Slave" series connection method is illustrated in FIG. 3-11. As seen from the figure, the reference voltage ($E_r$) of the "Slave" supply is disconnected and its input or null junction is connected to the output of the "Master" supply via the tracking resistor ($R_t$). The "Slave" supply output is thus completely dependent on the "Master" output voltage:

$$E_{os} = E_{om} \frac{R_{vcs}}{R_t}$$ , where:

$E_{om}$ = Output Voltage, Master
$E_{os}$ = Output Voltage, Slave
$R_t$ = Tracking Resistor
$R_{vcs}$ = Voltage Control Resistance, Slave

As evident from the equation above, if the tracking resistor ($R_t$) value is equal to that of the voltage control resistor of the "Slave" supply ($R_{vcs}$), a "tracking ratio of 1:1 is achieved and the output of the "Slave" will equal that of the "Master". If a single load is connected to the series "Master-Slave" combination, twice the "Master" output voltage is applied to it. If separate loads are connected, identical voltages are applied to the individual loads.

3-39 The ratio $E_{os}/E_{om}$ can be readily changed if the application so requires by simply altering the value of either $R_{vcs}$ or $R_t$. In practice, since $R_{vcs}$ is the ten-turn voltage control rheostat of the "Slave" supply, the tracking resistor ($R_t$) is selected for the desired tracking ratio. The value of $R_{vcs}$ is determined from the parts list and $R_t$ is selected accordingly to the selected ratio. For a 1:1 ratio $R_t = R_{vcs}$, for a 1:2 ratio, $R_t = 1/2\ R_{vcs}$ etc.

3-40 PROCEDURE FOR MASTER-SLAVE SERIES CONNECTION

a) Connect load as shown in FIG. 3-11. Keep voltage drop in the load wires as low as possible by using heavy gage wire.
b) Connect protective diodes across the respective output terminals.
c) Remove jumper links as shown (FIG. 3-11) and connect error sensing leads if remote sensing is desired. Sensing leads should be twisted and shielded.
d) Select value of the tracking resistor ($R_t$) and connect with shielded wire as shown (FIG. 3-11).
e) Turn supplies "on", and adjust output voltage on the "Master" Voltage Control as desired.

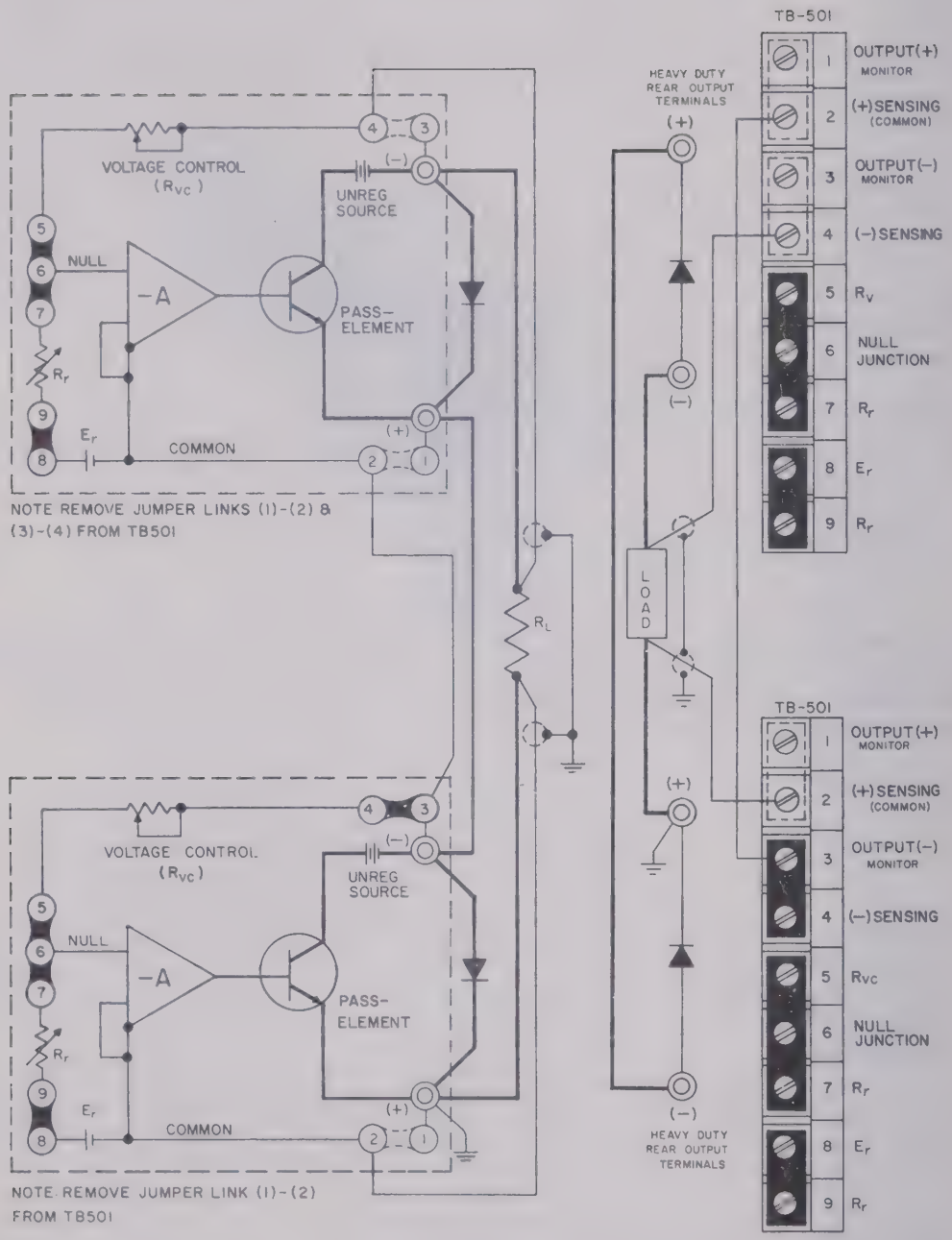



FIG. 3-10 AUTOMATIC SERIES CONNECTION OF KEPCO POWER SUPPLIES

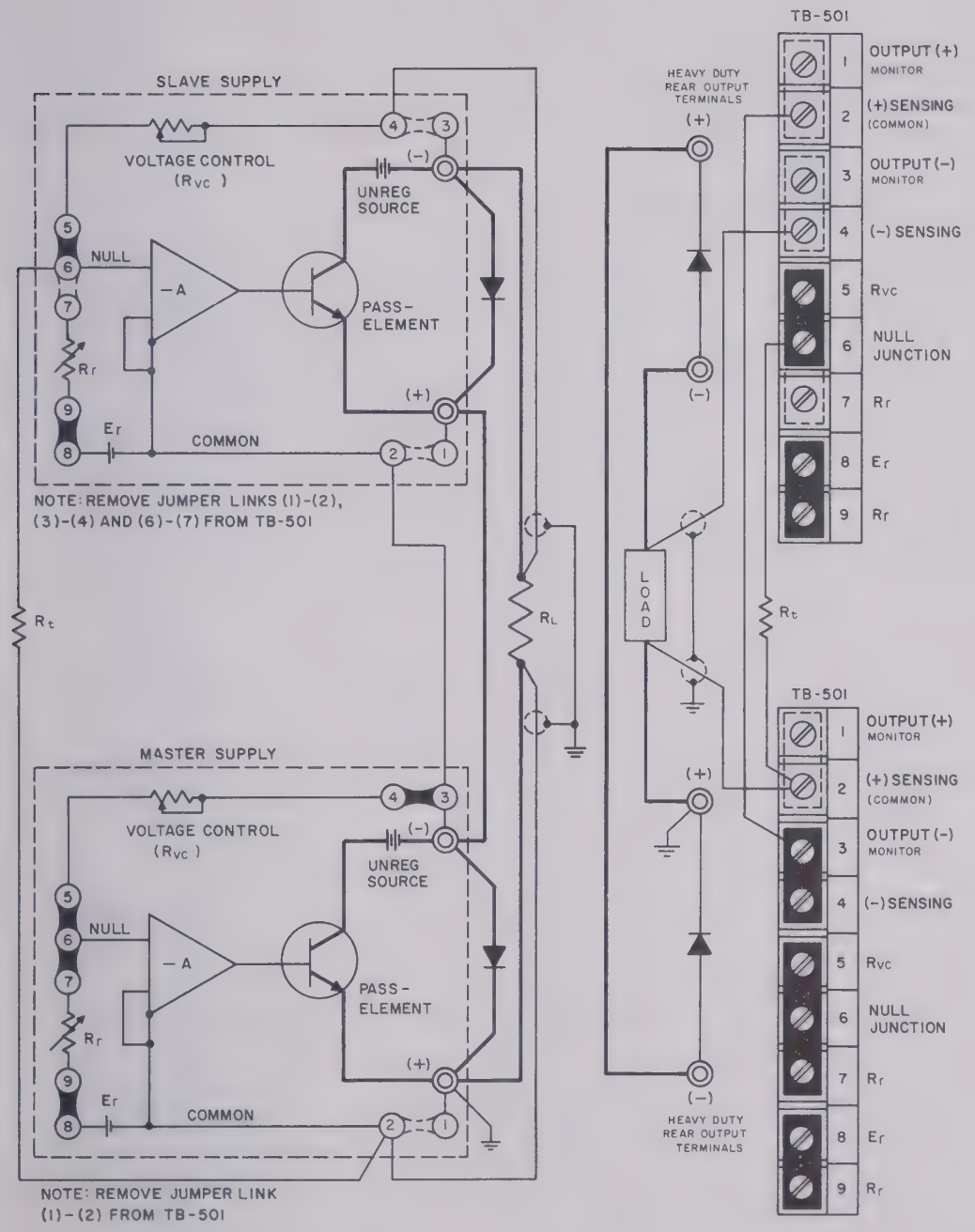



FIG. 3-11 MASTER-SLAVE SERIES CONNECTION OF KEPCO POWER SUPPLIES

## 3-41 PARALLEL OPERATION OF KEPCO POWER SUPPLIES

3-42 Two or more Kepco Power Supplies may be operated in parallel for increased load current output. Two parallel connection methods are generally used, the "Basic Parallel" connection as shown in FIG. 3-13 and the "Slave-Master" connection as illustrated in FIG. 3-14. The difference between these two alternate methods lies in the manner in which the output is controlled. While in the "Basic" Parallel connection the output is set individually, in the "Master-Slave" connection control is exercised from the "Master" supply alone. In effect, output current sharing must be individually adjusted with the "Basic" method and is automatic with the "Master-Slave" connection, the latter requiring however additional resistors, which may not always be readily available.

3-43 BASIC PARALLEL OPERATION. Two (or more) Kepco power supplies are connected with their outputs in parallel as shown in FIG. 3-13. Each supply is set approximately to the desired output voltage, with its respective current limit control at its maximum clockwise position. After turn-on, one of the supplies (#1 in FIG. 3-13) will be at a slightly higher voltage then the other (supply #2). Consequently, supply #1 will deliver all the load current up to the setting of its Current Control. As the load is increased beyond this limit of supply #1, supply #2 takes over and delivers the additional current. The Current Limiting Adjustment of supply #1 can now be descreased, so that approximately equal current sharing is obtained. FIG. 3-12 shows in form of a diagram, how the two supplies operate in parallel, with their respective Current Controls set to the maximum clockwise position (105% $I_O$ max.). It will be obvious from the diagram, that the areas of load regulation are within the output current bands of the individual supplies only. Therefore, load regulation cannot be measured from zero to twice the load current for example, but only within the individual load current bands. Error sensing as described in par. 3-4, from the supply operating in the "constant voltage" mode, supply #2 in the example may be used if precise regulation at the load is required.

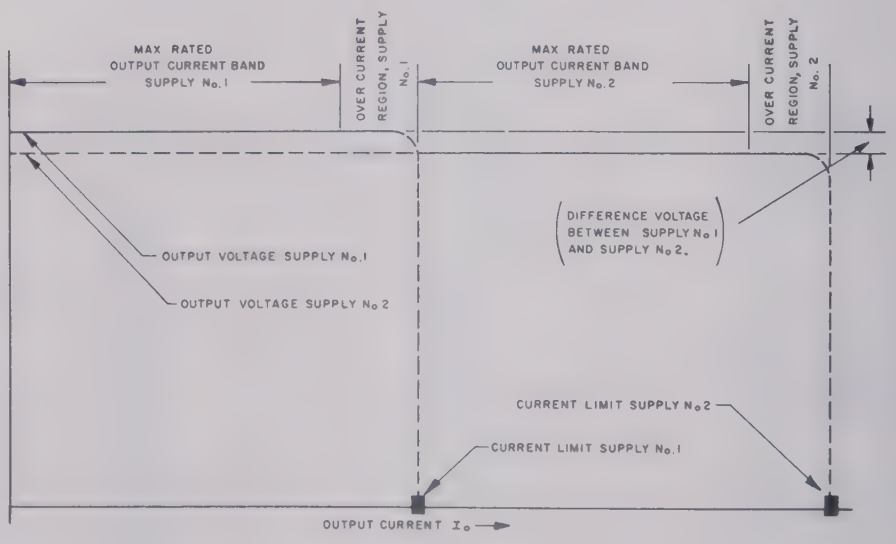



FIG. 3-12 PARALLEL OPERATION

3-44 PROCEDURE FOR BASIC PARALLEL CONNECTION (Refer to FIG. 3-13)

a) Connect units as shown in FIG. 3-13. Open SW-1 and connect to line.

b) Adjust both units to the approximate output voltage desired.

c) Close SW 1. Observe load current meters M1 and M2. Adjust Current Control on the unit showing the higher current on its load current meter. Turn Current Control counterclockwise until currents on M1 and M2 are approximately equal.

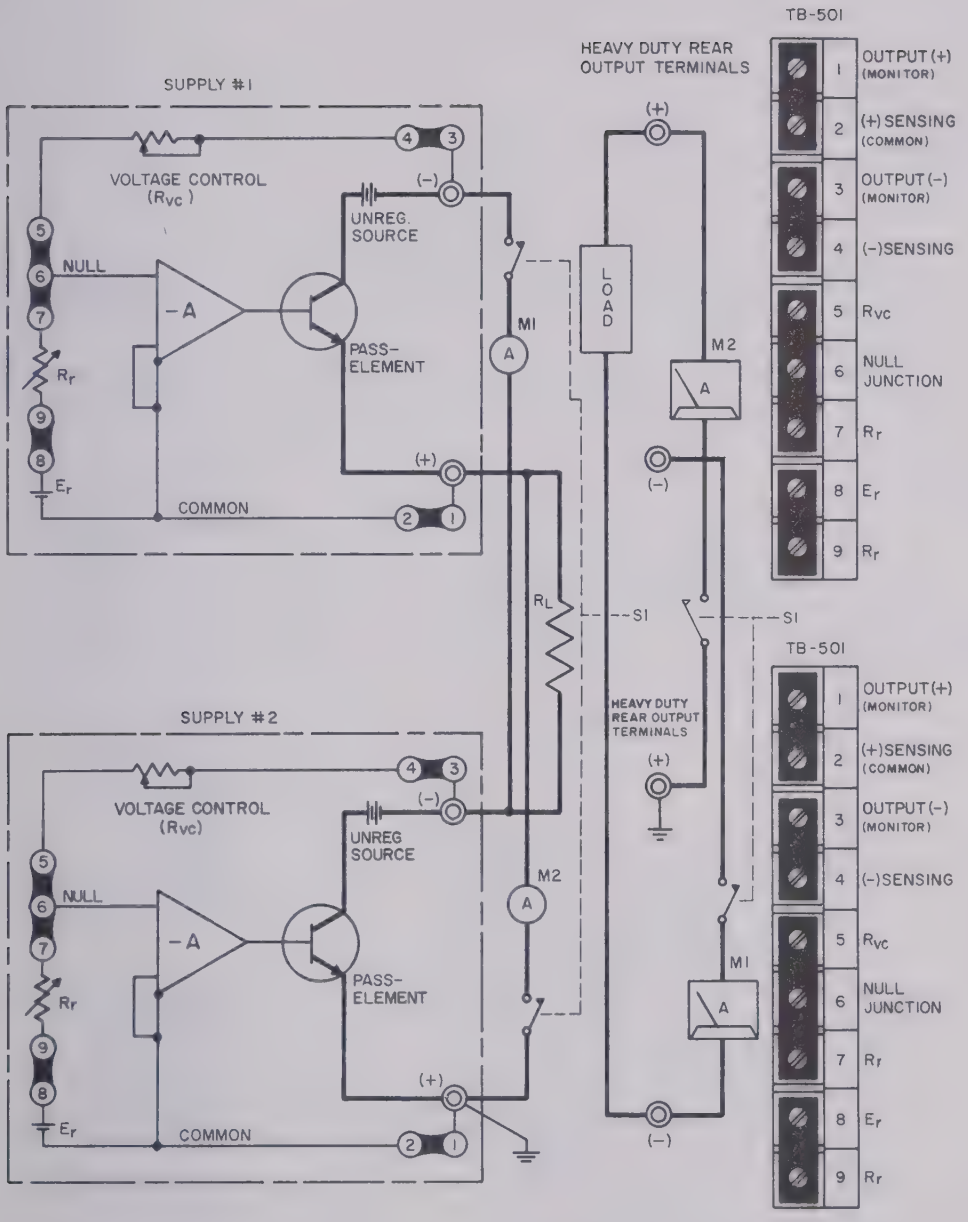



FIG. 3-13 BASIC PARALLEL CONNECTION OF TWO KEPCO POWER SUPPLIES

3-45 MASTER-SLAVE PARALLEL OPERATION. Kepco Power Supplies may be paralleled if the output current from a single supply is not sufficient for the application at hand. With the parallel connection shown in FIG. 3-14, the total output current of the parallel supplies may be controlled from a single "Master" supply. To operate the parallel supplies in the "Master-Slave" connection, sensing resistors of equal value must be selected ($R_{S1}$, $R_{S2}$ in FIG. 3-14) such that the voltage drop across them is about 0.1 to 0.25 volts at the output current of interest. The *sum* of the voltage drops across the load wire with the sensing resistor in series should *never exceed 0.5 volts* at the maximum desired operating current. If sensing resistors of the proper value are not available, the resistances of the load wires may be used to establish the necessary voltage drops. In this case, the load wires should be trimmed such that *equal voltage drops* are established in the lead from the "Master" and that from the "Slave" supply. Load wires should in general be of as heavy a wire gauge as practicable. Twisting of the load wires, as well as of the error sensing leads from the "Master" supply (although *not* shown in FIG. 3-14) is recommended.

3-46 PROCEDURE FOR "MASTER-SLAVE" PARALLEL CONNECTIONS

a) Select external current sensing resistors ($R_{S1}$ $R_{S2}$) as described.

b) Connect supplies as shown in FIG. 3-14, keeping load and error sensing leads as short as possible. Use shielded wire for the connection from terminal (2) of the "Master" to terminal (6) of the "Slave" unit.

c) Connect supplies to common AC power line and use common power switching.

d) After turn-on, output voltage can be adjusted on the Voltage Control of the "Master" supply and operation can commence.

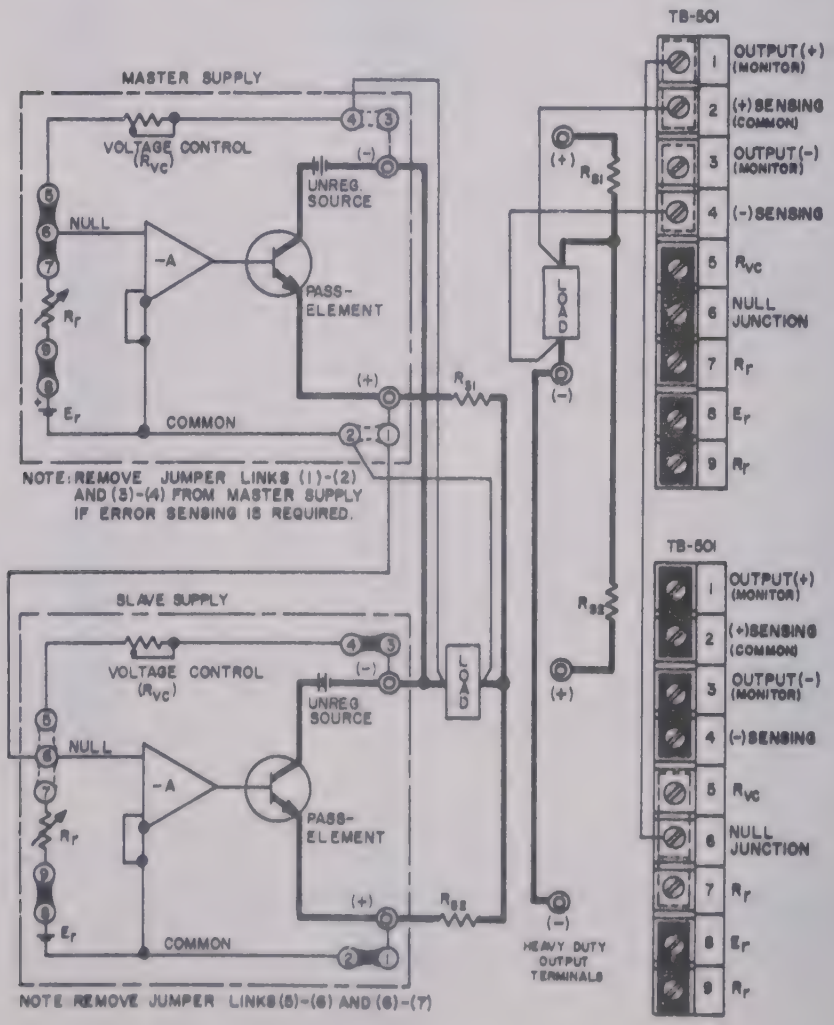



FIG. 3-14 MASTER SLAVE PARALLEL CONNECTION OF KEPCO POWER SUPPLIES

## SECTION IV – THEORY OF OPERATION

(References in CAPITAL LETTERS refer to the nomenclature used in FIG. 4-1)

### 4-1 SIMPLIFIED DIAGRAM DISCUSSION (Refer to FIG. 4-1)

4-2 The MAIN POWER TRANSFORMER converts the line voltage to the required levels needed to produce the DC operating voltages for the MAIN AND AUXILIARY SUPPLIES. The MAIN POWER SUPPLY is in series with the PASS ELEMENTS and the CURRENT SENSING RESISTOR and produces the output voltage. The MAIN PASS ELEMENTS are changing their series resistance in a way tending to keep the OUTPUT VOLTAGE constant. The necessary drive for this change is produced by the DRIVER CIRCUIT which in turn receives its command signals either from the CURRENT LIMIT AMPLIFIER or the ERROR SIGNAL AMPLIFIER.

4-3 The OUTPUT VOLTAGE is constantly compared to the REFERENCE SOURCE, while the output current is monitored by the CURRENT SENSING resistor. Any change, in either output voltage or current, is amplified by the associated amplifier and transfered to the GATE DIODES which feed directly into the DRIVER CIRCUIT and produce the needed drive signal for the MAIN PASS ELEMENTS, thus either keeping the OUTPUT VOLTAGE constant, or if the signal from the CURRENT LIMIT AMPLIFIER is dominant, limiting the output current to the pre-adjusted value.

4-4 The OVERVOLTAGE PROTECTOR (Optional, on models with suffix "VP" only.) is connected across the output terminals of the power supply. A portion of the output voltage is continuously compared to an internal reference. If an overvoltage occurrs, the S.C.R. "crowbar" will short-circuit the output immediately. Recycling takes place automatically, since the AC input power is removed by the tripping of the circuit breaker.

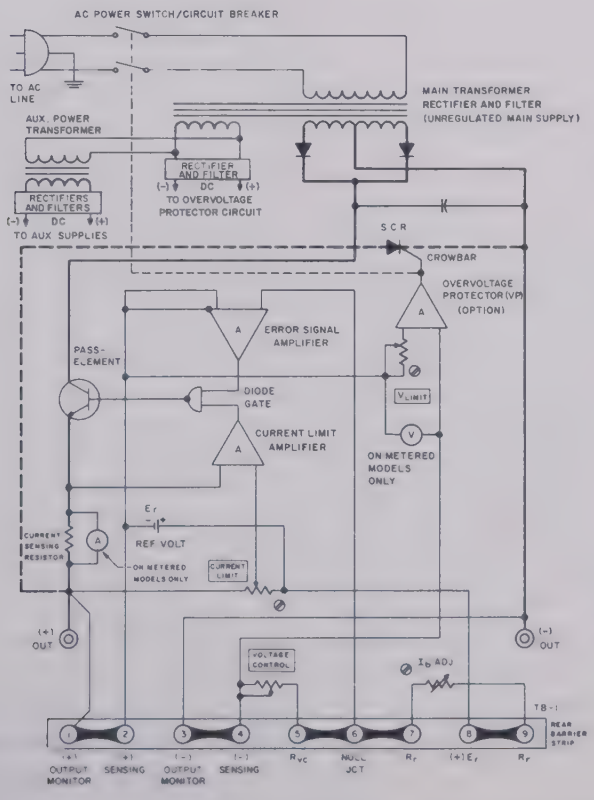



FIG. 4-1 SIMPLIFIED DIAGRAM,JQE HALF–RACK POWER SUPPLY

## 4-5 CIRCUIT DESCRIPTION

4-6 For the purpose of [illegible] the circuitry of the JQE power supply may be divided into several sections which are individually described below. The block diagram, [illegible] may be used to illustrate the text of this section.

a) AC INPUT CIRCUIT. AC line power is introduced through the AC input barrier-strip or a heavy duty three-wire line cord (removable) with safety plug.* The use of a grounded AC power outlet will automatically ground the power supply, since the third wire of the line cord is directly connected to the metal chassis and case. Once the AC POWER SWITCH/CIRCUIT BREAKER (CB101) is closed, the primary of the main transformer (T201), the fan (B201) and the AC pilot light (DS101)* will be energized. The two primary windings of the main transformer are either connected in parallel (for 115V AC nominal line voltage) or in series (for 230V AC nominal line voltage). The AC POWER SWITCH/CIRCUIT BREAKER (CB101), aside from switching the AC primary power, has the function of disconnecting the power supply from the AC line in case of overloads or short circuits. CB101 has two sensing coils, one of which is always in series with one of the primary windings on T201 (T2–T5), whether the main transformer is wired for 115V or for 230V AC. The second sensing coil of CB101 is in series with the secondary winding on T201 which [illegible] working potential for the overvoltage protection circuit (T201–T6,T7). If an overload occurs, due to either internal component failure or crowbar action of the voltage protector (Models with suffix "VP" only), the coil is energized sufficiently to activate the trip-mechanism of CB101, thus disconnecting the power supply from the AC line. Since the primary coil of the AUXILIARY POWER TRANSFORMER (T202) is in parallel with the secondary for the [illegible] any [illegible] auxiliary circuits, reflecting back to the primary of the auxiliary power transformer (T202) will also activate the sensing coil of CB101 and shut down the power supply. A thermal sensing element (S301) is mounted to the HEATSINK ASSEMBLY (A3) to protect the series regulator transistors from over-temperature. If the pre-set temperature on S301 is exceeded, its contact close and energize the sensing coil of CB101, resulting once more in the tripping of the [illegible] and subsequent removal of the AC input power from the power supply.

b) MAIN DC SUPPLY. [illegible] power is [illegible] from a center-tapped secondary winding on T201. A full-wave rectifier circuit with [illegible] (CR201,202 if located on A3, CR201,202 if located on main chassis A2) operates into a capacitor input filter (C201,202 on some models; C201,202,203 on others) which is paralleled by a [illegible] (R202). The main DC supply delivers the output current via the series regulator or pass-elements.

c) PASS-ELEMENT SECTION. The pass-element section in the JQE Power Supply varies in complexity according to the output voltage and current rating of the particular model. The NPN silicone pass-transistors of the JQE are located on high-efficiency heatsinks and are cooled by a fan (B201). Some JQE models have single heatsink assemblies (A3) with pass-transistors Q301 to Q3. .,. , the number depending on the individual model. Other JQE models have dual heatsink assemblies (A3 and A6) with pass-transistors Q301 to Q3. . . ,and Q601 to Q6. . . , the number of transistors again depending on the model involved. [illegible] low-voltage/high-current models ($E_o \leq 36$ volts) all pass-transistors are arranged in a parallel circuit, higher voltage models ($E_o > 36$ volts) use a series/parallel configuration in the arrangement of the pass-transistors. In the latter, a "master/slave" circuit is used, where the "slave" section is sometimes paralleled by power resistors, which share in the power dissipation if the power supply is operating in the current-limit mode or under short-circuit conditions. However complex the pass-element section, for analytical purposes it can be reduced to a single pass-transistor. Electrically, this pass-transistor is part of a series circuit consisting of the unregulated raw DC power source, the series pass-transistor, and the load resistor. The output voltage of the power supply is controlled regardless of changes in the load resistance by changing the series resistance of the control element (the pass-transistor) in the described series circuit. The necessary base-drive for the pass-transistors to affect the change in series resistance is supplied by the [illegible] connected to the base. The [illegible] stage in turn receives their base-signals from the pre-driver stage (Q2) of the error-signal amplifier.

*Line cord and AC pilot light used (required models [suffix "AC"] only. Unterminated models have an AC input barrier-strip. The terminal marked "E" or the [illegible] is connected directly to the chassis and must be returned to AC ground.

d) ERROR SIGNAL AMPLIFIER ($A_V$). The main function of this DC amplifier is to amplify the error signal, derived from the comparison bridge, to a level suitable to pass the diode gate circuit and drive the pre-driver stage (Q2). The error signal amplifier in the JQE power supply is a DC coupled, high gain operational amplifier in a plug-in package. The amplifier input may be disconnected from the comparison bridge circuit, and programmed externally. Although the plug-in amplifier is used in the non-inverting configuration, a positive input signal will produce a negative power supply output with respect to the "common" (plus (+) sensing terminal), since the pass-elements provide another signal inversion.

e) COMPARISON BRIDGE. This four-arm electrical bridge circuit is the sensing and controlling element in the JQE power supply. The reference-half of the bridge consists of the reference resistors in series with the zener reference voltage ($R_r$ = R4, R8; $E_r$ = CR3), the other half is constituted by the voltage control resistor ($R_{VC}$ = R102) and the output voltage ($E_O$). The simplified presentation shown in Section III of this manual will illustrate this discussion and show the actual bridge configuration. (Refer to FIG. 3-3). The output voltage (in series with $R_{VC}$) is continuously compared with the reference half of the bridge circuit. At bridge balance ($E_{AA'}$ = 0, a constant bridge current ($I_b$) is flowing through the bridge, keeping the error signal at the bridge terminals (A,A') at approximately zero volts. Any deviation in the output voltage ($E_O$), caused either by line/load variation or by a change in $R_{VC}$ will tend to change the bridge current ($I_b$) in the sensing half of the bridge and thereby produce an error signal at the bridge terminals (A,A'). The error signal is presented to the amplifier input and will after amplification, act as a drive for the pass transistors, changing the voltage drop ($E_p$) across them in such a way as to restore bridge balance and keep the output voltage ($E_O$) constant once more.

f) CURRENT LIMIT CIRCUIT. The differential input of the current limit amplifier (Q4,Q5) is connected to the current sensing resistor ($R_S$ = R203) and to a reference voltage, adjustable by the current limit control (R101). The voltage drop across the current sensing resistor is thus continuously compared to the reference voltage, set by the current limit control. As long as the voltage developed across $R_S$ (due to load current flow) is less than the pre-set voltage reference level, the current limit amplifier will be biased to its inactive state and will not effect the output. If the output current increases however, the voltage drop across $R_S$ will overcome the reference level set by the current limit control. The current limit amplifier will be thus activated and produce a drive signal at the diode gate, greater than $A_V$, thereby taking control away from the error signal amplifier and transferring the power supply into the current limit mode. Since both, the current limit amplifier and the error signal amplifier ($A_V$) are coupled through the diode gate circuit (CR14,15) to the pre-driver stage (Q2), the amplifier with the greater (negative) output will control the pass transistors and therefore the output.

g) OVERVOLTAGE PROTECTION CIRCUIT (A4, contained in Models with suffix–"VP")

1) Input and output connections for the overvoltage protection circuit (VP) are made via a single printed circuit board connector (P401) and its associated mating plug. The VP contains its own auxiliary power supply with only the AC voltage derived from a secondary of the main transformer (T201) and introduced via P401/J207. The AC is rectified by a conventional bridge rectifier (CR401), capacitor filtered by the input filter capacitor (C401) and shunt regulated by a zener diode (CR405). A six volt source is derived from the pre-regulated DC voltage by means of another zener diode (CR406) thus providing a stable reference source ($E_{ref}$).

2) The overvoltage protection circuit contains a dual input Schmitt-Trigger (Q402,403) in a voltage comparison configuration. A fixed part of the reference voltage ($E_{ref}$) is applied to the "reference input" (Base of Q402), and a portion of the power supply output voltage ($E_O$) to the "sensing input" (Base of Q403), so that the ratio $E_O/E_{ref}$ is continuously sampled. Adjustment of the "Voltage Limit" controls (R414,R415), connected as a part of the voltage divider on the "sensing input" keeps the ratio $E_O/E_{ref}$ constant, as the power supply output voltage is varied throughout the specified range (3V to $E_O$ max. rated). The inputs to the Schmitt Trigger are thus balanced and the circuit is inactive.

3) In the event of an overvoltage, resulting either from external causes or from internal power supply failure, the circuit become active. Since the "reference input" of the Schmitt Trigger is rigidly clamped to a fixed reference, a positive input at the "sensing input" (due for example to an overvoltage) will result in a change of state in Q402, producing an output pulse. The output

## 4-5 CIRCUIT DESCRIPTION

4-6 For the purpose of analysis, the circuitry of the JQE power supply may be divided into several sections which are individually described below. The main schematic (FIG. 6-1) should be used to illustrate the text of this section.

a) AC INPUT CIRCUIT. AC line power is introduced through the AC input barrier-strip or a heavy duty three-wire line cord (removable) with safety plug.* The use of a grounded AC power outlet will automatically ground the power supply, since the third wire of the line cord is directly connected to the metal chassis and case. Once the AC POWER SWITCH/CIRCUIT BREAKER (CB101) is closed, the primary of the main transformer (T201), the fan (B201) and the AC pilot light (DS101)* will be energized. The two primary windings of the main transformer are either connected in parallel (for 115V AC nominal line voltage) or in series (for 230V AC nominal line voltage). The AC POWER SWITCH/CIRCUIT BREAKER (CB101), aside from switching the AC primary power, has the function of disconnecting the power supply from the AC line in case of overloads or short circuits. CB101 has two sensing coils, one of which is always in series with one of the primary windings on T201 (T2–T5), whether the main transformer is wired for 115V or for 230V AC. The second sensing coil of CB101 is in series with the secondary winding on T201 which generates the working potential for the overvoltage protection circuit (T201–T6,T7). If an overload occurs, due to either internal component failure or crowbar action of the voltage protector (Models with suffix "VP" only), the coil is energized sufficiently to activate the trip-mechanism of CB101, thus disconnecting the power supply from the AC line. Since the primary coil of the AUXILIARY POWER TRANSFORMER (T202) is in parallel with the secondary for the overvoltage protection circuit, any failure in the auxiliary circuits, reflecting back to the primary of the auxiliary power transformer (T202) will also activate the sensing coil of CB101 and shut down the power supply. A thermal sensing element (S301) is mounted to the HEATSINK ASSEMBLY (A3) to protect the series regulator transistors from over-temperature. If the pre-set temperature on S301 is exceeded, its contact close and energize the sensing coil of CB101, resulting once more in the tripping of the AC POWER SWITCH/CIRCUIT BREAKER and subsequent removal of the AC input power from the power supply.

b) MAIN DC SUPPLY. The main DC power is derived from a center-tapped secondary winding on T201. A full-wave rectifier circuit with silicon diodes (CR301,302 if located on A3, CR201,202 if located on main chassis A2) operates into a capacitor input filter (C201,202 on some models; C201,202,203 on others) which is paralleled by a bleeder resistor (R202). The main DC supply delivers the output current via the series regulator or pass-elements.

c) PASS-ELEMENT SECTION. The pass-element section in the JQE Power Supply varies in complexity according to the output voltage and current rating of the particular model. The NPN silicone pass-transistors of the JQE are located on high-efficiency heatsinks and are cooled by a fan (B201). Some JQE models have single heatsink assemblies (A3) with pass-transistors Q301 to Q3. ... , the number depending on the individual model. Other JQE models have dual heatsink assemblies (A3 and A6) with pass-transistors Q301 to Q3. . . ,and Q601 to Q6. . . , the number of transistors again depending on the individual model. While in the low voltage/high output current models ($E_O \leqslant 36$ volts) all pass-transistors are arranged in a parallel circuit, higher voltage models ($E_O > 36$ volts) use a series/parallel configuration in the arrangement of their pass-transistors. In the latter, a "master/slave" circuit is used, where the "slave" section is sometimes paralleled by power resistors, which share in the power dissipation if the power supply is operating in the current-limit mode or under short-circuit conditions. However complex the pass-element section, for analytical purposes it can be reduced to a single pass-transistor. Electrically, this pass-transistor is part of a series circuit consisting of the unregulated main DC power supply, the external load and the pass-transistor. The output voltage of the power supply is kept constant, regardless of variations in the unregulated supply, by changing the series resistance of the control element (the pass-transistor) in the described series circuit. The necessary base-drive for the pass-transistors to affect the change in series resistance is supplied by the "Darlington" connected driver stage. The driver stages in turn receive their base signals from the pre-driver stage (Q2) of the error-signal amplifier.

*Line cord and AC pilot light used on metered models (suffix "M") only. Unmetered models have an AC input barrier strip. The terminal marked "G" on the barrier strip is connected directly to the chassis and must be returned to AC ground.

d) ERROR SIGNAL AMPLIFIER ($A_v$). The main function of this DC amplifier is to amplify the error signal, derived from the comparison bridge, to a level suitable to pass the diode gate circuit and drive the pre-driver stage (Q2). The error signal amplifier in the JQE power supply is a DC coupled, high gain operational amplifier in a plug-in package. The amplifier input may be disconnected from the comparison bridge circuit, and programmed externally. Although the plug-in amplifier is used in the non-inverting configuration, a positive input signal will produce a negative power supply output with respect to the "common" (plus (+) sensing terminal), since the pass-elements provide another signal inversion.

e) COMPARISON BRIDGE. This four-arm electrical bridge circuit is the sensing and controlling element in the JQE power supply. The reference-half of the bridge consists of the reference resistors in series with the zener reference voltage ($R_r$ = R4, R8; $E_r$ = CR3), the other half is constituted by the voltage control resistor ($R_{VC}$ = R102) and the output voltage ($E_o$). The simplified presentation shown in Section III of this manual will illustrate this discussion and show the actual bridge configuration. (Refer to FIG. 3-3). The output voltage (in series with $R_{VC}$) is continuously compared with the reference half of the bridge circuit. At bridge balance ($E_{AA'} = 0$, a constant bridge current ($I_b$) is flowing through the bridge, keeping the error signal at the bridge terminals (A,A') at approximately zero volts. Any deviation in the output voltage ($E_o$), caused either by line/load variation or by a change in $R_{VC}$ will tend to change the bridge current ($I_b$) in the sensing half of the bridge and thereby produce an error signal at the bridge terminals (A,A'). The error signal is presented to the amplifier input and will after amplification, act as a drive for the pass transistors, changing the voltage drop ($E_p$) across them in such a way as to restore bridge balance and keep the output voltage ($E_o$) constant once more.

f) CURRENT LIMIT CIRCUIT. The differential input of the current limit amplifier (Q4,Q5) is connected to the current sensing resistor ($R_s$ = R203) and to a reference voltage, adjustable by the current limit control (R101). The voltage drop across the current sensing resistor is thus continuously compared to the reference voltage, set by the current limit control. As long as the voltage developed across $R_s$ (due to load current flow) is less than the pre-set voltage reference level, the current limit amplifier will be biased to its inactive state and will not effect the output. If the output current increases however, the voltage drop across $R_s$ will overcome the reference level set by the current limit control. The current limit amplifier will be thus activated and produce a drive signal at the diode gate, greater than $A_v$, thereby taking control away from the error signal amplifier and transferring the power supply into the current limit mode. Since both, the current limit amplifier and the error signal amplifier ($A_v$) are coupled through the diode gate circuit (CR14,15) to the pre-driver stage (Q2), the amplifier with the greater (negative) output will control the pass transistors and therefore the output.

g) OVERVOLTAGE PROTECTION CIRCUIT (A4, contained in Models with suffix–"VP")

1) Input and output connections for the overvoltage protection circuit (VP) are made via a single printed circuit board connector (P401) and its associated mating plug. The VP contains its own auxiliary power supply with only the AC voltage derived from a secondary of the main transformer (T201) and introduced via P401/J207. The AC is rectified by a conventional bridge rectifier (CR401), capacitor filtered by the input filter capacitor (C401) and shunt regulated by a zener diode (CR405). A six volt source is derived from the pre-regulated DC voltage by means of another zener diode (CR406) thus providing a stable reference source ($E_{ref}$).

2) The overvoltage protection circuit contains a dual input Schmitt-Trigger (Q402,403) in a voltage comparison configuration. A fixed part of the reference voltage ($E_{ref}$) is applied to the "reference input" (Base of Q402), and a portion of the power supply output voltage ($E_o$) to the "sensing input" (Base of Q403), so that the ratio $E_o/E_{ref}$ is continuously sampled. Adjustment of the "Voltage Limit" controls (R414,R415), connected as a part of the voltage divider on the "sensing input" keeps the ratio $E_o/E_{ref}$ constant, as the power supply output voltage is varied throughout the specified range (3V to $E_o$ max. rated). The inputs to the Schmitt Trigger are thus balanced and the circuit is inactive.

3) In the event of an overvoltage, resulting either from external causes or from internal power supply failure, the circuit become active. Since the "reference input" of the Schmitt Trigger is rigidly clamped to a fixed reference, a positive input at the "sensing input" (due for example to an overvoltage) will result in a change of state in Q402, producing an output pulse. The output

pulse from the Schmitt Trigger stage, transferred via the emitter follower (Q401) is applied to the first S.C.R. (CR402). The charging time constant at the output of the Schmitt Trigger stage is determined by the value of the (adjustable) delay capacitor (C403). In effect, the setting of C403 determines the "sensitivity" to overvoltage of the protection circuit. Minimum capacity will yield faster response but will also make the circuit more sensitive to spurious triggering. The control is factory set for fastest response consistent with stable operation under all conditions.

4) As the first S.C.R. (CR402) is conducting due to the pulse from the Schmitt-Trigger, it performs two functions: It shorts out the DC supply for the voltage protection circuit, thereby creating an over current in one of the circuit breaker coils. Simultaneously, CR402 generates a firing pulse for the main S.C.R. (CR203), which through its "crowbar" action short-circuits the power supply output. The AC POWER SWITCH/CIRCUIT BREAKER (CB101) trips due to the action of the first S.C.R. (CR402), disconnecting the power supply from the power line. The protection circuit is automatically re-activated with the "turn-on" of the power supply via CB101.

h) AUXILIARY SUPPLIES

1) AMPLIFIER POWER SUPPLY. This full wave, bridge rectified source is derived from a secondary winding on the auxiliary transformer (T202). Rectified by CR8, the supply is capacitor filtered by C2. A current regulator stage (Q3), followed by a string of zener diodes (CR10–13), provides the operating voltage for the error signal amplifier ($A_V$), the current limit amplifier stage (Q4,Q5) and the reference circuit (R4,R8,CR3).

2) PRE-DRIVER COLLECTOR SUPPLY. A half wave rectified (CR3) and capacitor filtered (C2) supply is derived from a secondary winding on T202. It delivers collector voltage to the pre-driver stage (Q2).

3) $I_{CBO}$ SUPPLY. This full-wave rectified auxiliary supply is derived from the winding of the auxiliary power transformer. Rectified by CR1 and filtered by C1, constant current is applied to the base of the pass transistors (Via the constant current generator stage (Q1), thus insuring the necessary turn-off bias for these stages under all operating conditions, especially at elevated temperatures.

i) METERING CIRCUIT ( models with suffix "M" only). Both output voltage and output current are monitored by dual range front panel meters (M101,102). The two meter ranges are 0 to 10% and 0 to 100% of the rated output voltage and output current and may be selected by meter range switches (S101 for voltage, S102 for current) located between the front panel meters. While the output voltage is measured directly across the error sensing terminals (TB501–2, TB501–4), the output current is measured indirectly as a voltage drop across the current sensing resistor (R203).

# SECTION V – MAINTENANCE

## 5-1 GENERAL

5-2 This section covers maintenance procedures, installation of optional components, calibration and test measurements of the Kepco Model JQE Power Supplies. Conservative rating of components and the non-congested lay out should keep maintenance problems to a minimum. If trouble does develop however, the easily removed wrap-around cover and the plug-in feature of the circuit boards provide exceptional accessibility to all components of the supply.

## 5-3 DISASSEMBLY (Refer to FIG. 5-1)

a) COVER REMOVAL. The wrap-around cover may be taken off by loosening and removing its twelve (12) holding screws, five (5) on each side and two (2) on the front panel.

b) CIRCUIT BOARD REMOVAL. The printed circuit board is mounted with two (2) screws, which are removed from the side. After removal of the four printed circuit board connectors, the board may be lifted from its slide-guide.

c) HEAT SINK REMOVAL. The heat sink assembly is mounted with four (4) screws to the chassis bottom. After the screws are taken out, the wires may be removed by means of the "quick disconnect" terminals.

d) OVERVOLTAGE PROTECTOR (A4) REMOVAL. (On Models with Suffix–"VP" only). Remove the holding screw as indicated (Refer to FIG. 5-1) and lift assembly out.

e) RE-ASSEMBLY. Re-assembly of all components takes place in reverse order of the above described procedures.

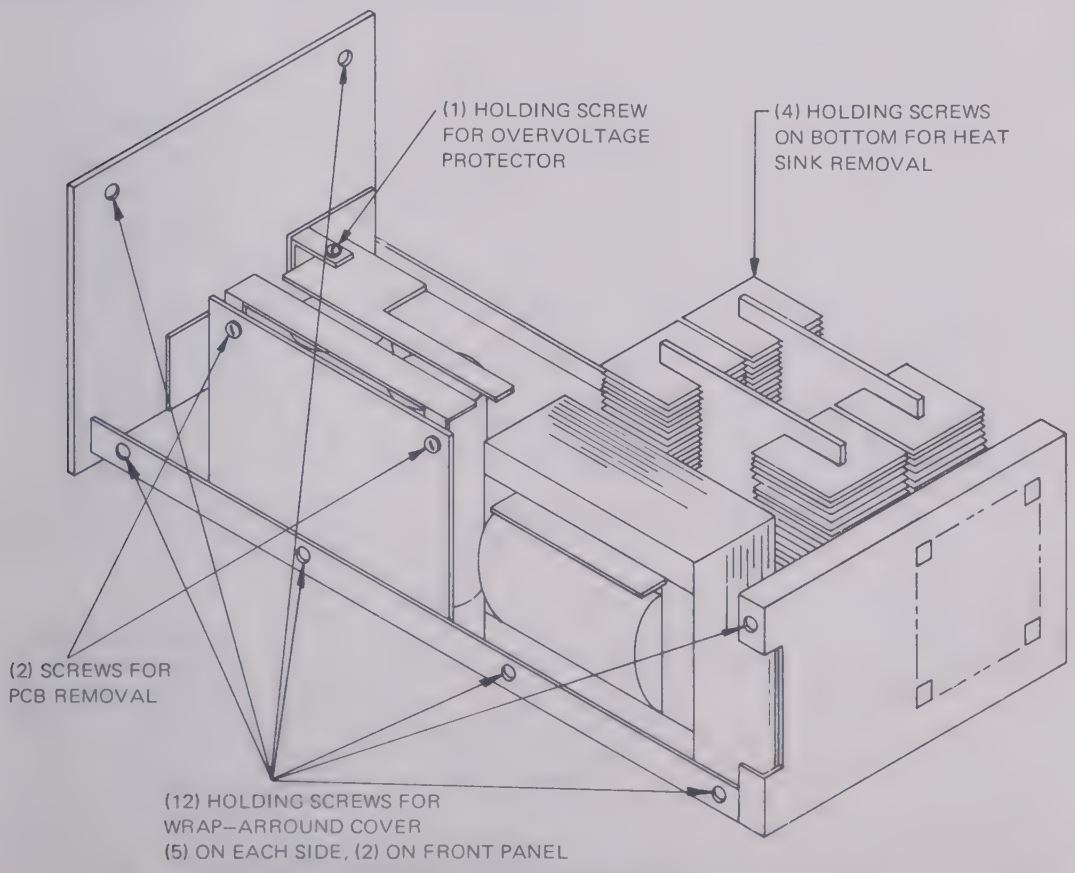

(1) HOLDING SCREW FOR OVERVOLTAGE PROTECTOR
(4) HOLDING SCREWS ON BOTTOM FOR HEAT SINK REMOVAL
(2) SCREWS FOR PCB REMOVAL
(12) HOLDING SCREWS FOR WRAP–ARROUND COVER (5) ON EACH SIDE, (2) ON FRONT PANEL

FIG. 5-1 DISASSEMBLY, JQE HALF–RACK MODELS

## 5-4 INTERNAL ADJUSTMENT PROCEDURES

5-5 GENERAL. This paragraph describes all internal adjustment procedures, which have not been previously covered. Refer to Section II, paragraph 2-3, for a listing and location of all adjustment procedures.

5-6 MAXIMUM OUTPUT CURRENT ("$I_O$ max. adj.") ADJUSTMENT. This adjustment serves as a calibration for the range of the front panel Current Limit Control. The "$I_O$ max. adj." (R19) is located on the printed circuit board (Refer to FIG. 2-1). It is factory set so that the front panel control covers an output current range of 2–105% of the maximum rated output current. Re-adjustment of the "$I_O$ max. adj." control is needed only if a component in the current limit circuitry must be replaced or, if the range of the front panel control is to be restricted. A convenient way to make the adjustment is as follows:

a) Load the output of the supply to draw the maximum desired output current with the front panel Current Limit Control fully clockwise. Monitor the output voltage with an oscilloscope, having a vertical sensitivity of at least 0.1 mV/cm.

b) Observe the oscilloscope. Current limiting is indicated by a sharp increase in output ripple. Locate the "$I_O$ max. adj." control and turn slowly until limiting occurs at the point required. Clockwise adjustment will increase the maximum output current range, while counter clockwise adjustment will decrease the range. DO NOT ADJUST TO MORE THAN 105% $I_O$ max. Although this might be possible due to component tolerances, malfunction of the power supply will be caused by exceeding the rated maximum output current.

5-7 LAG NETWORK ADJUSTMENTS. Depending on the JQE model designation, either one or two AC stability controls in the form of lag networks have been provided in this power supply (R16-C9 and/or R36-C10, see main schematic, FIG. 6-3). These networks have been factory adjusted for maximum amplifier stability when operating into a resistive load. Re-adjustment is indicated if components, affecting the AC characteristics of the amplifier must be replaced or, if the load connected to the power supply contains excessive capacity or inductance, causing AC instability. AC instability is usually indicated by high frequency oscillation as observed with an oscilloscope across the power supply load. In such cases, the lag networks should be adjusted so that stable operation is resumed. If in extreme cases adjustment of the lag networks should not prove sufficient, twisted load and error sensing wires or decoupling capacity directly across the load may provide a solution to the problem.

## 5-8 INSTALLATION AND ADJUSTMENT OF THE "ZERO" CONTROL *

**NOTE:** Models which have this control factory installed carry the suffic "E" behind their model number (i.e. JQE 6–10ME). The installation instructions may be disregarded with these models.

5-9 A small (5–15mV), negative offset voltage exists at the output of the power supply, with the voltage control set to "zero" (fully counter clockwise). Although this does not affect standard power supply operation, for precision remote programming, exact zero volt output may be necessary. The zero can be established by adding the necessary control ("$E_{io}$ Null," to be designated R14) internally on a pre-designated space on the printed circuit board.

5-10 The installation may be readily accomplished by following the steps indicated below:

a) Remove thy PCB Assembly from the chassis as described in paragrpah 5-3. Locate the pre-designated space for the additional components on FIG. 5-2.

b) Install "$E_{io}$ Null" (R14) control on the place indicated and solder in place.

c) Remove old jumper and install in new place as shown.

d) Adjust precision zero as described in paragraph 3-12.

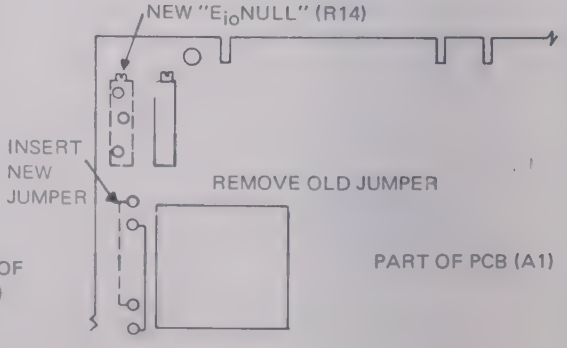



FIG. 5-2 INSTALLATION OF $E_{io}$ NULL (ZERO) CONTROL

*These instructions are applicable for Models JQE 6–45(M) and JQE 15–25(M) only.

## 5-11 TROUBLE SHOOTING

5-12 Modern, high performance power supplies have reached a state of sophistication that requires thorough understanding of the problems involved in repairing complex, solid state circuitry. Servicing beyond simple parts replacements should consequently be attempted only by personnel thoroughly familiar with solid state component techniques and with experience in closed loop circuitry.

5-13 Trouble shooting charts, showing resistance and voltage readings, are of very limited usefulness with feedback amplifiers and are not included here. Instead a detailed circuit description (Section IV), parts location diagrams, simplified functional schematics and a main schematic with all significant voltage readings is presented.

5-14 The following basic steps in a case of power supply malfunctioning may also be found useful:

a) If power supply does not function at all: Check all powerline connections and fuses and make certain, power supply is connected to the correct line voltage (it is normally delivered for 115V AC operation).

b) No DC Output:
   1) Check rear barrier-strip jumper connection for correct placement and tight seat (Refer to FIG. 4-1).
   2) Check the correct placement and tight seat of all transistors on the amplifier board (Refer to the component location drawings and parts list in Section VI).
   3) Check reference voltage from terminal (2) to (8) on the rear barrier strip. Correct reference potential is 6.2V nominal.
   4) Check amplifier supply voltages from the "0 V DC" buss. (Refer to Main Schematic, FIG. 6-3)
   5) Test amplifier transistors* Q2, Q3, Q4.

c) HIGH DC OUTPUT: If the output voltage is high and not controllable by the voltage control, identical steps as outlined above (par. 5-14b) are advisable. In addition, if the condition persists, check the following:
   1) Check the pre-driver transistor* (Q1) and the main driver (Q305) as well as all pass-elements (Q301–3..., the number of pass-elements depends on the individual model).
   2) Check the voltage control resistor (R102) for continuity. Monitor output with an oscilloscope and observe ripple wave-form and amplitude. If high frequency oscillations are observed proceed as directed below. (Refer to par. 5-14e). High 60 Hz ripple is often due to failure in one of the rectifier circuits. Measure the operating voltages under the conditions specified in the main schematic (FIG. 6-3).

d) If supply does not function in one of the remote programming modes, disconnect all external components and reconnect internal reference and the voltage control. The following paragraphs refer to the instrument as a power supply, rather than an amplifier in order to simplify test set-ups and measurements.

e) If the power supply is basically functioning, but poor performance is evident, inspect the test set-up to make certain the source of the trouble is not external.

f) Excessive output variations in any of the operating modes are usually traceable to incorrectly connect loads or faulty measurement techniques. Perform measurements as described in paragraph 5-16 and follow the connecting diagrams.

g) Oscillation of the output voltage or output current is often due to a load with a large inductive component. Twisted loadwires of sufficient diameter and held as short as practical, are often the solution to the problem, if lag network adjustment does not correct the trouble. (Refer to par. 5-7).

5-15 KEPCO Field Engineering Offices or the KEPCO Repair Department will be available for consultation or direct help in difficult service or application problems.

*NOTE: If a transistor checker is not available, transistors may be checked for shorts by means of an ohmmeter. Check between emitter and collector and reverse polarity of the ohmmeter. One reading should be high, the other low, the ratio being about 1:4.

## 5-16 POWER SUPPLY MEASUREMENTS

5-17 Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or after component replacement. Since the measurements require special techniques to insure correct results, suggestions for their performance are given below:

a) Required Instrumentation:

1) Constant AC source voltage with provisions for "stepping" the voltage over a specified region (105–125V); a variable autotransformer is generally adequate, if it is rated to deliver the input current of the unit under test.

2) Resistive load, variable with CONTROL and SHORTING SWITCH and capable of dissipating the full output power of the unit under test.

3) DC voltage monitor, differential voltmeter, or power supply analyzer.

4) Current sensing resistor, for measurements of output effects in the current mode, 4-terminal device.

5) AC ripple monitor, sensitivity better than 1 mV, Ballantine Model 302C or Hewlett Packard Model 400H.

6) Optional: Oscilloscope, vertical sensitivity better than 0.1 mV/cm.

b) FIG. 5-3 shows the proper location of instrument leads when measuring output effects. The principle governing this method of measurement is simply: DO NOT MEASURE ANY VOLTAGE DROPS DUE TO LOAD CURRENT FLOW. This can only be avoided by measuring output effects either directly at the sensing leads or by the use of 4-terminal network. The 4-terminal network can be approximated by the method shown in FIG. 5-3d.

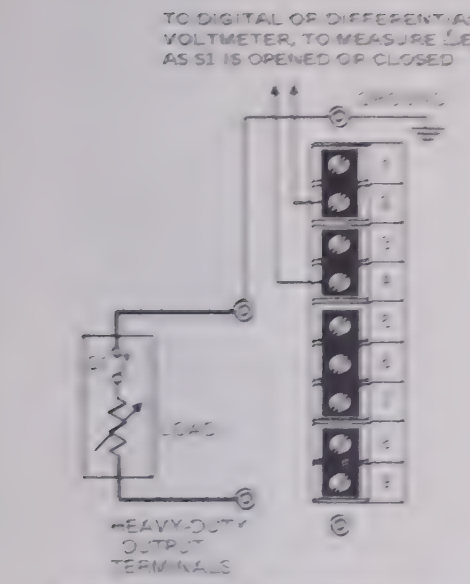
c) Output effects due to source or load variations in the voltage mode are defined as the amount of output voltage change resulting from a specified change of line voltage or from a change in load resistance. It can be expressed as an absolute change $\Delta E_o$ or as a percentage in reference to the total output voltage $E_o$:

$$\% \text{ Output Effect} = \frac{\Delta E_o}{E_o} \times 100\%$$

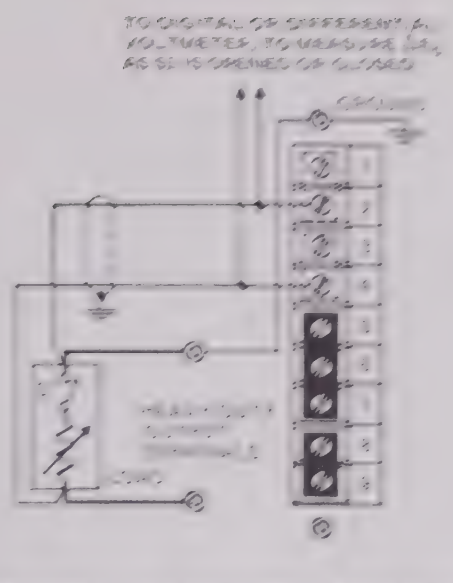
d) Output effects due to source or load variations in the current mode are defined as the amount of output current change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change $\Delta I_o$ or as a percentage in reference to the total output current $I_o$:

$$\% \text{ Output Effect} = \frac{\Delta I_o}{I_o} \times 100\%$$

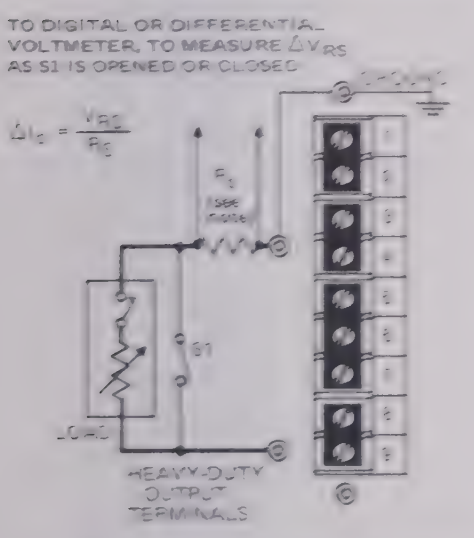
e) RMS ripple may be monitored on a true RMS reading instrument connected parallel to the regulation analyzer leads. Careful wire dressing and shielding, as well as good AC grounding are of the utmost importance if valid measurements are expected. An oscilloscope may also be used for P-P readings of noise and ripple. An approximate RMS reading can be calculated from the P-P reading of the oscilloscope if the reading is divided by three.




a) OUTPUT EFFECT MEASUREMENT (VOLTAGE) WITHOUT ERROR SENSING

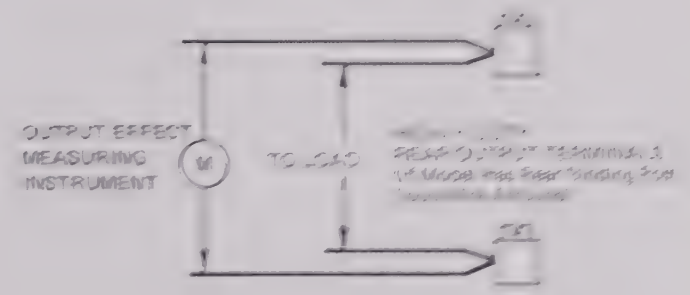


b) OUTPUT EFFECT MEASUREMENT (VOLTAGE) WITH ERROR SENSING AT THE LOAD


TO DIGITAL OR DIFFERENTIAL VOLTMETER, TO MEASURE $\Delta V_{RS}$ AS S1 IS OPENED OR CLOSED
$\Delta I_o = \frac{V_{RS}}{R_S}$
$R_S$ (SEE NOTE)
S1
LOAD
HEAVY-DUTY OUTPUT TERMINALS

c) OUTPUT EFFECT MEASUREMENT (CURRENT)

NOTE: $R_S$ should be selected such that its wattage rating is at least 10 times the actual power dissipated. Stability and regulation depend on the stability of $R_S$. Recommended T.C. for $R_S$ is 20 ppm.




d) APPROXIMATION OF A SENSE-TERMINAL NETWORK

FIG. 5-3 CONNECTIONS FOR POWER SUPPLY MEASUREMENTS

# SECTION VI – ELECTRICAL PARTS LIST AND DIAGRAMS

## 6-1 GENERAL

6-2 This section contains the main schematic, the parts location diagrams, and a list of all replaceable electrical parts. All components are listed in alpha-numerical order of their reference designations. Consult your Kepco Representative for replacement of parts not listed here.

## 6-3 ORDERING INFORMATION

6-4 To order a replacement part or to inquire about parts not listed in the parts list, address order or inquiry either to your authorized Kepco Sales Representative or to:

KEPCO, INC.
131–38 Sanford Avenue
Flushing, N.Y. 11352

6-5 Specify the following information for each part:

a) Model and complete serial number of instrument.

b) Kepco part number.

c) Circuit reference designator.

d) Description.

6-6 To order a part not listed in the parts list, give a complete description and include its function and location.

**AMPLIFIER BOARD ASSEMBLY (A1), MODEL JQE 36–15(M) (T) (E)** **Code 4-870**

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| $A_V$ | 1 | Plug-In Amplifier | Kepco 250-0013 | 250-0013 |
| C1 | 1 | Capacitor,Electrolytic,Pigtail 150 μF, 25 V | Sprague 30D157G025DF0 | 117-0713 |
| C2 | 1 | Capacitor,Electrolytic,Pigtail 75 μF, 50 V | Sprague 30D756G0050DF2 | 117-0646 |
| C3,4 | 2 | Capacitor,Electrolytic,Pigtail 150 μF, 3 V | General Electric 7602BF151 | 117-0512 |
| C5 | 1 | Capacitor,Mylar,Pigtail 0.1 μF, 600 V | TRW X663F | 117-0316 |
| C6 | 1 | Capacitor,Mylar,Pigtail 1 μF, 200 V | Wesco 33MM | 117-0395 |
| C7 | 1 | Capacitor,Electrolytic,Pigtail 150 μF, 15 V | Sprague 30D157G15DD2 | 117-0677 |
| C8 | 1 | Capacitor,Mylar,Pigtail 0.05 μF,200 V | Sprague 192P10302 | 117-0315 |
| C10 | 1 | Capacitor,Mylar,Pigtail 2 μF, 200 V | TRW X663F | 117-0129 |
| CR1,6,8 | 3 | Rectifier,Silicon,Bridge,Pigtail | TRW X663F | 124-0346 |
| CR2,9,10, 12,13 | 5 | Zener Diode | Transitron 1N763-1 | 121-0028 |
| CR3,11 | 2 | Zener Diode | International Resistance 1N821 | 121-0041 |
| *CR3 | 1 | Zener Diode | International Resistance 1N827 | 121-0062 |
| CR4,5 | 2 | Rectifier,Silicon,Pigtail | EDI CEC 1000 | 124-0178 |
| CR7,14,15 | 3 | Rectifier,Silicon,Pigtail | Semtech SE-1 | 124-0133 |
| CR16 | 1 | Rectifier,Silicon,Pigtail | Semtech SE-4 | 124-0028 |
| **CR17 | 1 | Zener Diode | International Resistance 1N821 | 121-0041 |
| Q1 | 1 | Transistor | RCA 2N3054 | 119-0060 |
| Q2,3 | 2 | Transistor | M.S. Transistor 119-0094 | 119-0094 |
| Q4,5 | 2 | Transistor | Fairchild 2N5133 | 119-0093 |
| R1 | 1 | Resistor,Fixed,Molded 130 ohm, 1/2 W, 5% | Allen Bradley EB1315 | 115-1859 |
| R2 | 1 | Resistor,Fixed,M.G. 3 K ohm, 1/4 W, 5% | IRC RG 1/4 | 115-2294 |
| R3 | 1 | Resistor,Fixed,Molded 560 ohm, 1/2 W, 5% | Allen Bradley EB5615 | 115-0888 |
| R4 | 1 | Resistor,Variable,WW 1 K ohm, 1/2 W, 10% | Amphenol Control Div. 2600P-102 | 115-2264 |
| R5 | 1 | Resistor,Fixed,Molded 560 ohm, 1/4 W, 5% | IRC GBT 1/4 | 115-2210 |

*Models with suffix "T" only.
**Models with suffix "E" only.

NOTE:
REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

AMPLIFIER BOARD ASSEMBLY (A1), MODEL JQE 36–15(M) (E) Code 4-870

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| R6 | 1 | Resistor,Fixed,Precision,M.F.<br>10 K ohm, 1/4 W, 1% | IRC<br>CEA | 115-2174 |
| R7 | 1 | Resistor,Fixed,Precision,M.F.<br>750 ohm, 1/4 W, 1% | IRC<br>CEA | 115-2259 |
| R8 | 1 | Resistor,Fixed,Precision,M.F.<br>5.7 K ohm, 1 W, 1% | Tepro<br>TS-1W | 115-1301 |
| R9 | 1 | Resistor,Fixed,Precision,M.F.<br>210 ohm, 1 W, 1% | Tepro<br>TS-1W | 115-1936 |
| R10 | 1 | Resistor,Fixed,M.G.<br>82 K ohm, 1/4 W, 5% | IRC<br>RG 1/4 | 115-2012 |
| R11 | 1 | Resistor,Fixed,Molded<br>3.9 K ohm, 1/2 W, 5% | Allen Bradley<br>EB3925 | 115-0808 |
| R12,26 | 2 | Resistor,Fixed,Molded<br>1 K ohm, 1/2 W, 5% | Allen Bradley<br>EB1025 | 115-0340 |
| *R13 | 1 | Resistor,Fixed,M.G.<br>1.3 K ohm, 1/4 W, 5% | IRC<br>RG 1/4 | 115-2379 |
| **R14 | 1 | Resistor,Variable,Trimpot,Cermet<br>100 K ohm, 3/4 W | Bourns<br>3009P-1-104 | 115-2399 |
| R15 | 1 | Resistor,Fixed,Precision,M.F.<br>40.2 K ohm, 1/4 W, 1% | IRC<br>CEA | 115-2391 |
| **R15 | 1 | Resistor,Fixed,Precision,M.F.<br>10 K ohm, 1/4 W, 1% | IRC<br>CEA | 115-2174 |
| R17 | 1 | Resistor,Fixed,Molded<br>47 ohm, 1/4 W, 10% | IRC<br>GBT 1/4 | 115-2273 |
| R18 | 1 | Resistor,Fixed,Molded<br>47 K ohm, 1/4 W, 10% | IRC<br>GBT 1/4 | 115-2237 |
| R19 | 1 | Resistor,Variable,Cermet<br>20 K ohm, 3/4 W, 10% | Bourns<br>309P-203 | 115-2393 |
| R20 | 1 | Resistor,Fixed,M.G.<br>6.2 K ohm, 1/4 W, 5% | IRC<br>RG 1/4 | 115-2258 |
| R21 | 1 | Resistor,Fixed,Molded<br>12 K ohm, 1/4 W, 10% | IRC<br>GBT 1/4 | 115-2276 |
| R23 | 1 | Resistor,Fixed,Molded<br>27 ohm, 1/4 W 10% | IRC<br>GBT 1/4 | 115-2317 |
| R24 | 1 | Resistor,Fixed,Molded<br>5.6 K ohm, 1 W, 10% | Allen Bradley<br>GB5621 | 115-0546 |
| R25,27 | 2 | Resistor,Fixed,Molded<br>10 ohm, 1/4 W, 10% | IRC<br>GBT 1/4 | 115-2230 |
| R28 | 1 | Resistor,Fixed,Molded<br>1.2 K ohm, 1/2 W, 5% | Allen Bradley<br>EB1225 | 115-1167 |
| **R29 | 1 | Resistor,Fixed,Precision,M.F.<br>750 ohm, 1/4 W, 1% | IRC<br>CEA | 115-2259 |
| **R30,31 | 2 | Resistor,Fixed,Precision,M.F.<br>43.2 K ohm, 1/4 W, 1% | IRC<br>CEA | 115-2380 |
| R34 | 1 | Resistor,Fixed,Precision,M.F.<br>210 ohm, 1/4 W, 1% | Tepro<br>TS-1W | 115-2177 |
| R36 | 1 | Resistor,Variable,Cermet<br>100 ohm, 3/4 W, 10% | Bourns<br>3009P-1-101 | 115-2396 |

*Delete for Models with suffix "E" only.
**Models with suffix "E" only.

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**MAIN CHASSIS AND FRONT PANEL ASSEMBLY (A2), MODEL JQE 36–15(M)** Code 4-870

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| **FRONT PANEL ASSEMBLY CONTAINS:** | | | | |
| CB101 | 1 | Circuit Breaker | Heinemann VA2-A6A3 | 127-0253 |
| *DS101 | 1 | Pilot Light Assembly | Industrial Devices Glo-Dot 2100 | 152-0087 |
| *M101 | 1 | Meter 0-15A DC | Honeywell Model 504 | 135-0434 |
| *M102 | 1 | Meter 0-40V DC | Honeywell Model 504 | 135-0448 |
| R101 | 1 | Resistor,Variable,Composition 2 K ohm, 1/2 W, 30% | CTS VA-45 | 115-2268 |
| R102 | 1 | Resistor,Variable,WW 40 K ohm, 3 W, 3% | Bourns 3507 | 115-1238 |
| *S102,103 | 2 | Switch | Stackpole SS-72-1 | 127-0254 |
| *Metered Models only. | | | | |
| B201 | 1 | Motor | Howard Industries 23112 | 148-0027 |
| C201,202 | 2 | Capacitor,Electrolytic,Can 15.6 K μF, 75V | General Electric 86F100 | 117-0765 |
| C204 | 1 | Capacitor,Electrolytic,Can 3600 μF, 50V | General Electric 86F500 | 117-0734 |
| C205 | 1 | Capacitor,Mylar,Pigtail 0.01 μF, 400V, 10% | Sprague 192P10304 | 117-0361 |
| CR201,202 | 2 | Rectifier,Silicon,Stud | International Rectifier 40HF20 | 124-0354 |
| *CR203 | 1 | Silicon,Controlled,Rectifier (SCR) | International Rectifier 40RCS5 | 124-0322 |
| CR204 | 1 | Rectifier,Silicon,Pigtail | Semtech SE-4 | 124-0028 |
| R201 | 1 | Resistor,Fixed,Power,Axial 7.5 ohm, 5 W, 5% | Tepro TS-5W | 115-0982 |
| R202 | 1 | Resistor,Fixed,Power,Axial 1 K ohm, 5 W, 5% | Tepro TS-5W | 115-0512 |
| R203 | 1 | Resistor,Fixed,Power,Shunt 0.033 ohm, 50 W, 1% | Tepro TMK-50W | 115-2332 |
| R204 | 1 | Resistor,Fixed,Power Ribbon 3.65 ohm, 750 W, 5% | Kepco Magnetics 115-2473 | 115-2473 |
| T201 | 1 | Transformer | Kepco Magnetics 100-1891 | 100-1891 |
| T202 | 1 | Transformer | Kepco Magnetics 100-1865 | 100-1865 |

*Models with suffix "VP" only.

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# REPLACEMENT PARTS LIST

**PASS-ELEMENT ASSEMBLY (A3), MODEL JQE 36–15(M)** **Code 4-870**

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| C301 | 1 | Capacitor,Mylar,Pigtail 0.1 μF, 200 V | Sprague 192P10492 | 117-0363 |
| CR301 | 1 | Rectifier,Silicon,Pigtail | Semtech SE-1 | 124-0133 |
| Q301,302, 303,304, 306,307, 308,309 | 8 | Transistor | Solitron 93SE163 | 119-0061 |
| Q305,310 | 2 | Transistor | RCA 2N3054 | 119-0060 |
| R301,302, 303,304, 307,308, 309,310 | 8 | Resistor,Fixed,Power,Axial 0.1 ohm, 3 W, 5% | Tepro TS-3C | 115-0819 |
| R305,311 | 2 | Resistor,Fixed,Molded 100 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2231 |
| R306,313 | 2 | Resistor,Fixed,Molded 1 K ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2238 |
| R312 | 1 | Resistor,Fixed,Molded 22 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2494 |
| R314 | 1 | Resistor,Fixed,Power,Axial 1 K ohm, 1 W, 5% | Tepro TS-5W | 115-0512 |
| R315 | 1 | Resistor,Fixed,Molded 10 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2230 |
| S301 | 1 | Thermostat | Stemco 110486 | 127-0248 |

NOTE:

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# REPLACEMENT PARTS LIST

*VOLTAGE PROTECTOR ASSEMBLY (A1), MODEL JQE 36–15(M) VP — Code 4-870

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| C401 | 1 | Capacitor,Electrolytic,Pigtail 140 μF, 40V | Sangamo 052FE141W040B | 117-0706 |
| C402 | 1 | Capacitor,Mylar,Pigtail 0.05 μF, 200V | TRW X663F | 117-0315 |
| C403 | 1 | Capacitor,Variable 80–480 pF, 175V | Arco PC46 | 117-0637 |
| C404 | 1 | Capacitor,Mylar,Pigtail 0.0068 μF, 200V | TRW X663F | 117-0552 |
| CR401 | 1 | Rectifier,Silicon,Bridge,Pigtail | Varo VE-28 | 124-0346 |
| CR402 | 1 | Rectifier,Controlled,Silicon (SCR) | Motorola 2N4441 | 124-0349 |
| CR403 | 1 | Zener Diode | Transitron 1N746A | 121-0060 |
| CR404,406 | 2 | Zener Diode | Transitron 1N763-1 | 121-0028 |
| CR405 | 1 | Zener Diode | Motorola 1N3024B | 121-0057 |
| Q401,402,403 | 3 | Transistor,NPN | General Electric 2N336A | 119-0056 |
| R401 | 1 | Resistor,Fixed,Power,Axial 0.5 ohm, 3 W, 5% | Hardwick Hindle 9/166A-46-0.5 | 115-0504 |
| R402 | 1 | Resistor,Fixed,Molded 10 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2230 |
| R403 | 1 | Resistor,Fixed,Molded 330 ohm, 2 W, 5% | Allen Bradley HB3305 | 115-0882 |
| R404 | 1 | Resistor,Fixed,Molded 100 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2231 |
| R405,408,413 | 3 | Resistor,Fixed,Molded 1 K ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2238 |
| R406 | 1 | Resistor,Fixed,Precision,M.F. 1.1 K ohm, 1/4 W, 1% | IRC CEA | 115-2176 |
| R407 | 1 | Resistor,Fixed,Precision,M.F. 6.04 K ohm, 1/4 W, 1% | IRC CEA | 115-2175 |
| R409 | 1 | Resistor,Fixed,Precision,M.F. 3.92 K ohm, 1/4 W, 1% | IRC CEA | 115-2179 |
| R410 | 1 | Resistor,Fixed,Precision,M.F. 1.5 K ohm, 1/4 W, 1% | IRC CEA | 115-2178 |
| R411 | 1 | Resistor,Fixed,Precision,M.F. 210 ohm, 1/4 W, 1% | IRC CEA | 115-2177 |
| R412 | 1 | Resistor,Fixed,Precision,M.F. 10 K ohm, 1/4 W, 1% | IRC CEA | 115-2174 |
| R414 | 1 | Resistor,Variable,Trimpot,WW 20 K ohm, 1/2 W | Amphenol Controls Division 2600P-203 | 115-2267 |
| R415 | 1 | Resistor,Variable,M.F. 1 megohm, 1/2 W, 10% | Bourns 3009P-1-202 | 115-2404 |

*Not used in models with suffix "HS" (High Speed).

NOTE:
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*VOLTAGE PROTECTOR ASSEMBLY (A1), MODEL JQE 36–15(M) VP Code 4-870

| SCHEMATIC NO. | QTY. | DESCRIPTION | MFRS. NAME & PART NO. (SEE NOTE) | KEPCO PART NO. |
|---|---|---|---|---|
| C401 | 1 | Capacitor,Electrolytic,Pigtail 140 μF, 40V | Sangamo 052FE141W040B | 117-0706 |
| C402 | 1 | Capacitor,Mylar,Pigtail 0.05 μF, 200V | TRW X663F | 117-0315 |
| C403 | 1 | Capacitor,Variable 80–480 pF, 175V | Arco PC46 | 117-0637 |
| C404 | 1 | Capacitor,Mylar,Pigtail 0.0068 μF, 200V | TRW X663F | 117-0552 |
| CR401 | 1 | Rectifier,Silicon,Bridge,Pigtail | Varo VE-28 | 124-0346 |
| CR402 | 1 | Rectifier,Controlled,Silicon (SCR) | Motorola 2N4441 | 124-0349 |
| CR403 | 1 | Zener Diode | Transitron 1N746A | 121-0060 |
| CR404,406 | 2 | Zener Diode | Transitron 1N763-1 | 121-0028 |
| CR405 | 1 | Zener Diode | Motorola 1N3024B | 121-0057 |
| Q401,402,403 | 3 | Transistor,NPN | General Electric 2N336A | 119-0056 |
| R401 | 1 | Resistor,Fixed,Power,Axial 0.5 ohm, 3 W, 5% | Hardwick Hindle 9/166A-46-0.5 | 115-0504 |
| R402 | 1 | Resistor,Fixed,Molded 10 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2230 |
| R403 | 1 | Resistor,Fixed,Molded 330 ohm, 2 W, 5% | Allen Bradley HB3305 | 115-0882 |
| R404 | 1 | Resistor,Fixed,Molded 100 ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2231 |
| R405,408,413 | 3 | Resistor,Fixed,Molded 1 K ohm, 1/4 W, 10% | IRC GBT 1/4 | 115-2238 |
| R406 | 1 | Resistor,Fixed,Precision,M.F. 1.1 K ohm, 1/4 W, 1% | IRC CEA | 115-2176 |
| R407 | 1 | Resistor,Fixed,Precision,M.F. 6.04 K ohm, 1/4 W, 1% | IRC CEA | 115-2175 |
| R409 | 1 | Resistor,Fixed,Precision,M.F. 3.92 K ohm, 1/4 W, 1% | IRC CEA | 115-2179 |
| R410 | 1 | Resistor,Fixed,Precision,M.F. 1.5 K ohm, 1/4 W, 1% | IRC CEA | 115-2178 |
| R411 | 1 | Resistor,Fixed,Precision,M.F. 210 ohm, 1/4 W, 1% | IRC CEA | 115-2177 |
| R412 | 1 | Resistor,Fixed,Precision,M.F. 10 K ohm, 1/4 W, 1% | IRC CEA | 115-2174 |
| R414 | 1 | Resistor,Variable,Trimpot,WW 20 K ohm, 1/2 W | Amphenol Controls Division 2600P-203 | 115-2267 |
| R415 | 1 | Resistor,Variable,M.F. 1 megohm, 1/2 W, 10% | Bourns 3009P-1-202 | 115-2404 |

*Not used in models with suffix "HS" (High Speed).

NOTE:
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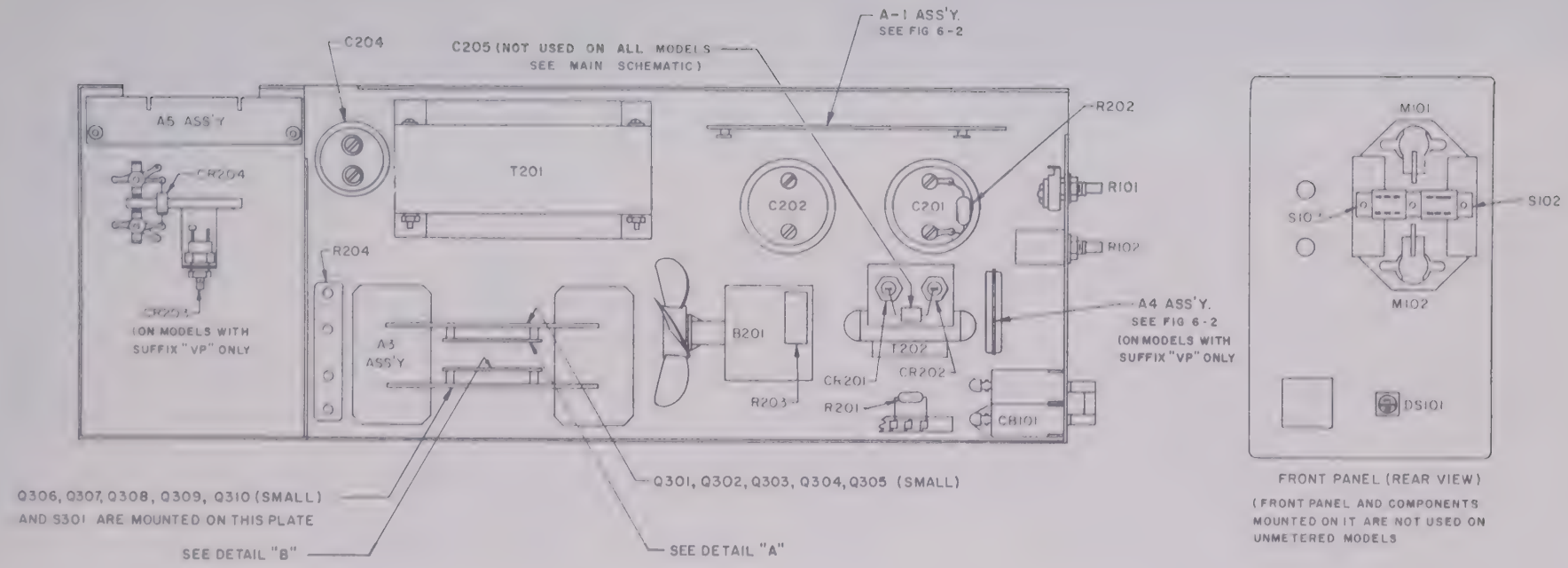
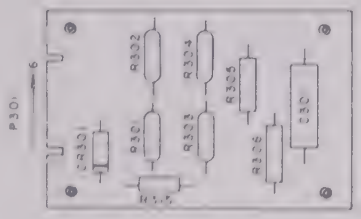


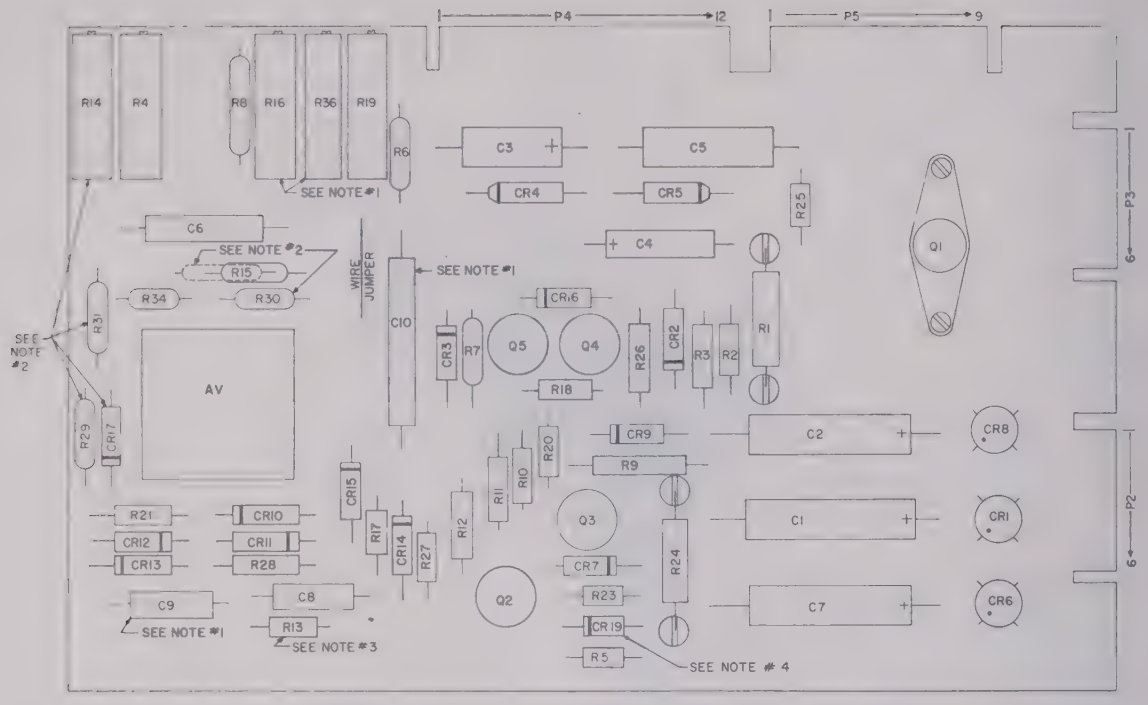




DETAIL "A"

DETAIL "B"

THIS DWG IS USED FOR THE FOLLOWING MODELS
JQE 25-20(M), JQE 36-15(M), JQE55-10(M) &
JQE 75-8(M)

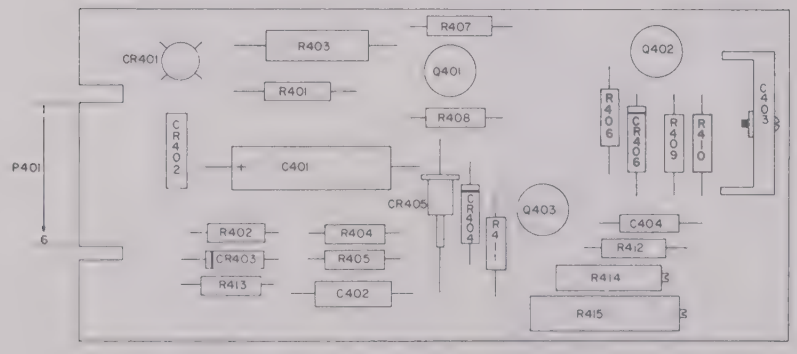
FIG 6-1 COMPONENT LOCATION, CHASSIS AND AUXILIARY BOARDS




NOTES

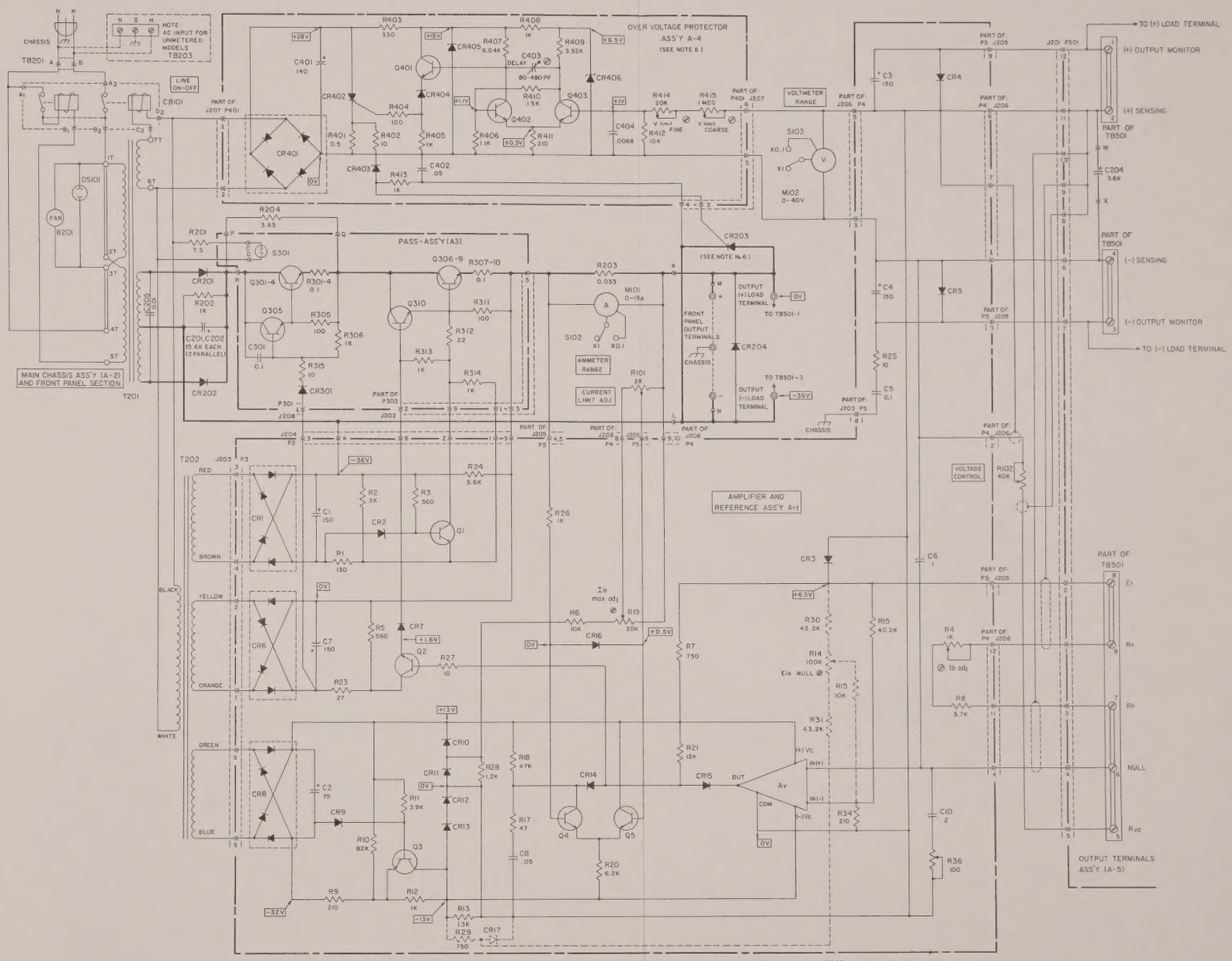
1. LAG ADJ I(R36,C10) AND LAG ADJ II(R16,C9) NOT ON ALL MODELS, SEE MAIN-SCHEMATIC.
2. ON ALL MODELS WITH SUFFIX "E"
3. NOT ON MODELS WITH SUFFIX "E"
4. CR19 IS NOT USED ON ALL MODELS, SEE MAIN SCHEMATIC.

a) AMPLIFIER (A1) ASS'Y




b) VOLTAGE PROTECTOR (A4) ASS'Y

FIG. 6-2 COMPONENT LOCATION, AMPLIFIER AND VP ASSEMBLY




NOTES:

1. RESISTOR VALUES IN OHMS, K=1000.
2. CAPACITOR VALUES IN MICROFARADS, UNLESS OTHERWISE INDICATED.
3. CONNECTORS MARKED WITH CAPITAL LETTERS ARE "QUICK DISCONNECT" TERMINALS. CONNECTORS SUFFIXED "T" ARE TRANSFORMER TERMINALS.
4. VOLTAGE READINGS TAKEN UNDER THE FOLLOWING CONDITIONS:
   A) LINE AT 115 V AC, Eo = MAX. RATED, Io = 0.
   B) METER, 20K OHM/VOLT
   C) ALL VALUES WITH REFERENCE TO THE POSITIVE (+) SENSING TERMINAL, EXCEPT IN THE OVERVOLTAGE PROTECTOR CIRCUIT, WHERE THE VOLTAGES ARE WITH RESPECT TO THE NEGATIVE (-) SENSING TERMINAL.
5. MI01, MI02, SI02, SI03, DSI01 AND FRONT PANEL OUTPUT TERMINALS, IN METERED UNITS ONLY.
6. THE OVERVOLTAGE PROTECTOR (ASS'Y A-4) WITH COMPONENT NUMBERS 400-499 AND CR203 IS AN OPTIONAL ASS'Y AND IS USED IN MODELS WITH SUFFIX "VP" ONLY.
7. COMPONENTS SHOWN WITH DASHED LINES ARE USED IN MODELS WITH SUFFIX "E" ONLY. R13 (1.3K) AND R15 (40.2K) ARE DELETED IN THESE MODELS.

TB501

| | |
|---|---|
| 1 | (+) OUTPUT MONITOR |
| 2 | (+) SENSING |
| 3 | (-) OUTPUT MONITOR |
| 4 | (-) SENSING |
| 5 | Rvc |
| 6 | NULL JUNCTION |
| 7 | Rr |
| 8 | Er |
| 9 | Rr |

FIG. 6-3 MAIN SCHEMATIC, MODEL JQE 36-15(M).

kepco® Data subject to change without notice
PATENT NOTICE: Applicable Patent Nos. will be supplied on request.

KEPCO

# INSTRUCTION MANUAL CORRECTION

Please note the following corrections to the manual material as indicated:

Parts List and Schematic Diagram:

| | | | | |
|---|---|---|---|---|
| 1. CHANGE: | CB101 | Circuit Breaker | | Kepco# 127-0253 to: |
| | CB101 | Circuit Breaker | | Kepco# 127-0286. |
| 2. DELETE: | C205 | Capacitor, Mylar, Pigtail | 0.01μf, 400V, 10% | Kepco# 117-0361. |
| 3. ADD: | C206, C207 | Capacitor, Ceramic | 0.1μf, 500V, +80%, -20% | Kepco# 118-0087. |
| 4. CHANGE: | Q3 | Transistor, Silicon, NPN | | Kepco# 119-0094 to: |
| | Q3 | Transistor, Silicon, NPN | | Kepco# 119-0059. |

NOTE: C205 has been removed from its previous location. C206 and C207 have been added and are connected in parallel to CR201 and CR202 respectively.

| | | | | |
|---|---|---|---|---|
| 5. DELETE: | R12 | Resistor, Fixed, Molded | 1K ohm, ½W, 5% | Kepco# 115-0340 |
| 6. ADD: | C11 | Capcitor, Ceramic, Disc | .005MF, 500V | Kepco# 117-0061. |

Note: C11 has been added to assembly A1. It is connected between the collector and emitter of Q3.

JQE 36-15(M)(VP)/2-271/r3 C2530
JQE 36-15(M)(VP)/8-2471/r4 C2704
JQE 36-15(M)(VP)/3-672/r5 C2814
JQE 36-15(M)/8-2272/r6 C2968

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